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Electric Furnace Heating

By George Turner, M.Inst.M.

The advantages of electric heat-energy for heat-treatment operations depend on the design of the furnace used. A large number of designs have been developed to meet the requirements of various operations and products, and in this article the author discusses briefly some "Russ" designs.

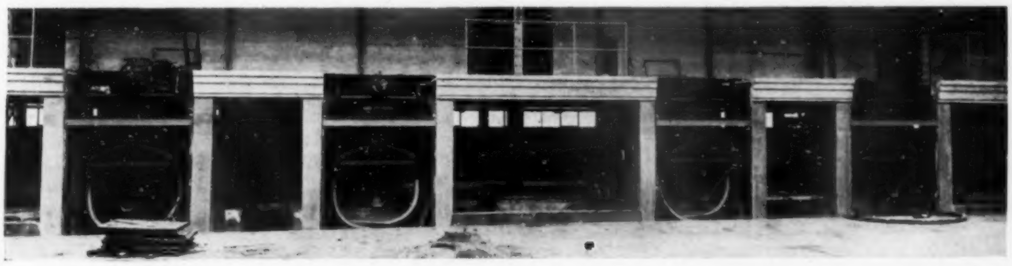

Fig. 1.—Part of a battery of ten induction melting furnaces.

DURING the comparatively short time that the value of electric heating has been appreciated for melting and general heat-treatment, remarkable progress has been made in the design of electric furnaces, both in England and abroad, to meet the demands of modern works practice. The improved technique which has been developed in these operations is largely dependent upon heat control; this factor has an important influence on the quality and uniformity of the product, and the simplicity and accuracy of the control of electric energy for these purposes has led to its increasing application.

In the electric furnace the heat-energy is directed into definite channels, and there is a fixed distribution with absolute control over the rate of flow, but the furnace must be designed to take full advantage of the benefits of electric energy for a particular operation. It should be regarded as a tool, and in order to give efficient service a great number of designs have been developed to meet requirements that the diversity of operations and products involve.

Considerable research has been directed towards the development of furnaces with the primary object of improving the quality of their products to enable them to meet the more rigid specifications now in use. Among many other designers the results of researches by Herr E. Fr. Russ, of the "Industrie" Elektroofen G.m.b.H., Cologne, are of considerable interest, as will be appreciated from the following notes and illustrations which represent some of the electric-furnace plant designed and built under his direction.

Induction Melting Furnaces.

The name "Russ" is usually associated with the Russ patent induction melting furnace, which is of outstanding merit. Fig. 1 shows part of a battery of ten induction melting furnaces having capacities of 600 kgs. each, which have been in successful operation for some years in a large works in Northern France. These are used for the melting of brass, copper, and cupro-nickel alloys.

Owing to the furnace, as its name implies, being heated on the induction principle, with the charge acting as the secondary of the built-in transformer, and also owing to the special design of the hearth, a gentle swirl is obtained which ensures a thorough mixing of the constituents of the charge. The hearth of this furnace is of crucible shape, having a minimum of bath surface, which has the effect of decreasing the oxidising influences and resulting in a minimum of metal loss.

A further point of interest and an outstanding feature of the design is to be found in the importance of the substantial layer of insulation surrounding the hearth, as is shown in a cross-section of the furnace, Fig. 2. This, it will be readily appreciated, has a direct influence on the current consumption.

These furnaces are suitably rated to give an output of 20 full charges in 24 hours, and as many as 9,000 heats of yellow brass have been obtained with a single furnace lining.

Aluminium Hearth-type Melting Furnaces.

The furnace shown in Fig. 3 is a resistance-heated hearth-type melting furnace, and is one of many such furnaces

Fig. 5.—A continuous strip annealing and pickling plant.

installed, and proved eminently successful for the melting of aluminium and aluminium alloys. It consists of a central melting chamber with heated charging chutes arranged at each end, both of the latter serving as preheating chambers. The heating elements, which are of substantial cross-section, are arranged in the form of a sinuous winding across the entire roof of the furnace, and a valuable feature of the arrangement lies in the ease with which the elements may be removed and replaced when necessary. In order to obviate any damage through contact with the charge, the elements are protected by heat-resisting alloy plates. Further, the furnace body is conveniently mounted on a radial cradle supported on four rollers, which enables it to be easily tipped for the purpose of pouring.

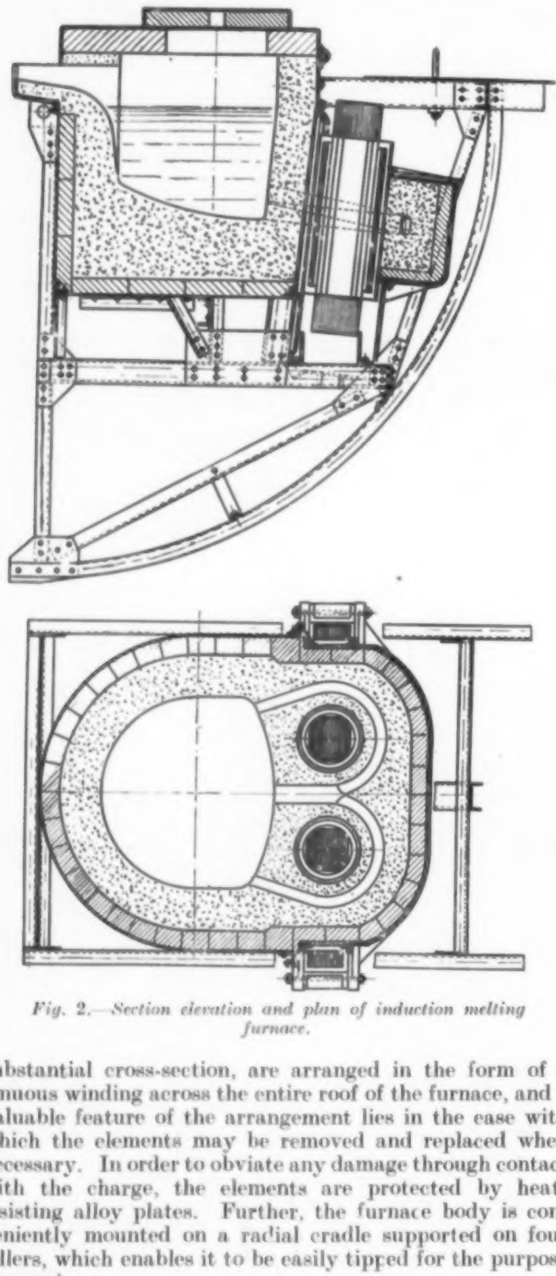

Fig. 2.—Section elevation and plan of induction melting furnace.

This tilting-hearth metallic resistor type of furnace, a section of which is shown in Fig. 4, is designed for an output up to 15 tons per 24 hours, with a current consumption varying between 370-500 kwh. per ton, depending upon the charge and method of working. These figures speak for themselves, whilst the metal loss is lower than 1%—a negligible quantity.

Continuous Strip Annealing and Pickling Plant.

During recent years mass production methods have had a considerable influence on the design of heat-treatment equipment. Efforts have been made to reduce dependence on the skill of the operator in heat-treatment and subsequent operations; these have led to many improvements in furnace equipment, and both automatic and semi-automatic methods of handling have been developed. The type, design, and arrangement of furnace, cooling, and other units, necessary to form complete automatic equipment, have a considerable influence on the overall cost of production, and where conditions permit such equipment provides ideal practice.

The continuous strip annealing and pickling plant shown in Fig. 5 was specially designed to supply a need for a plant which would continuously anneal strip and automatically subject it to all the necessary processes attendant on annealing, and finally deliver the strip as a perfectly clean and annealed product. It consists of an electrically heated annealing furnace, cooling tank, electrically heated pickling bosh, washing machine, electrically heated drying furnace, and strip coiling device, all arranged in line, enabling the full sequence of operations to follow without the strip being handled.

This plant is built for outputs ranging from 6 to 24 tons per 24 hours, and to accommodate strip or strips having a maximum width of 14 in. to 40 in., and the overall current consumption for the complete operation of annealing, pickling, and drying varies between 100 and 130 kwh. per ton, depending upon the width and thickness of the strip.

Furnace for Bright Annealing Non-ferrous Sheets.

A recent development is an electric furnace for the bright annealing of copper and brass sheets. For ease of manipulation this furnace is mounted on a steel gantry, the underside of the furnace being about 6 ft. 6 in. above the floor level. The dimensions of the annealing chamber are 18 ft. 9 in. by 11 ft. 6 in. by 3 ft. 6 in. The sheets to be annealed are piled up on a rail truck and shielded from the atmosphere by means of an air-tight cover made of heat-resisting alloy sheet 0·1 in. thick, suitably reinforced. The loaded truck is driven under the furnace, and, by means of a hydraulic plunger lifted into the annealing chamber, the truck frame, together with axles and wheels remaining outside. During the annealing process the truck is held in position by means

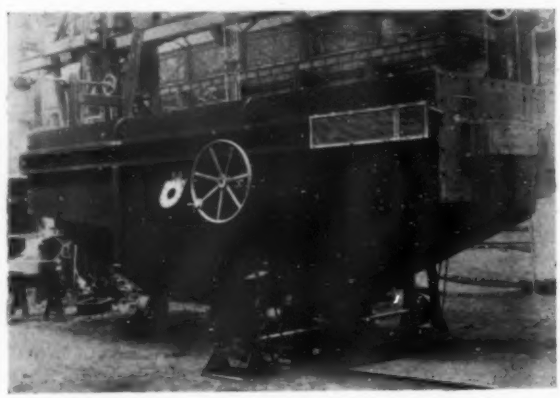

Fig. 3.—Resistance-heated hearth-type melting furnace.

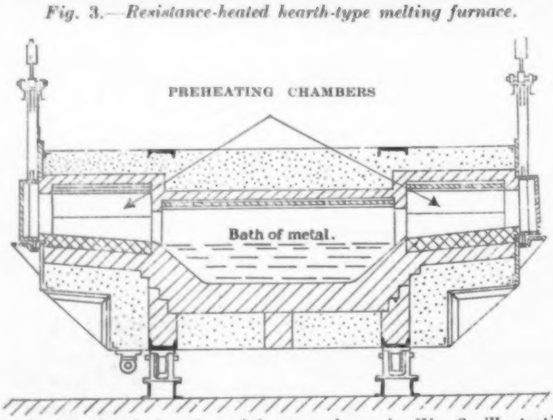

Fig. 4.—Sectional elevation of furnace shown in Fig. 3, illustrating the arrangements.

(*Continued on page* 4)

Surface Hardening Scientifically

By A. E. SHORTER, M.B.E., M.I.MECH.E.

Hardened surfaces that are dependable in service must be produced under absolute control, otherwise irregular hardening will result and produce variations in surface metal stresses.

THE whole question of local hardening is greatly confused in the mind of some designers, managers, buyers, and others whose business it is to obtain results, but who do not always find it possible to go into detail and to distinctly classify between right and wrong methods of treatment. Too often the price factor governs the finished job without regard to science or to the ultimate service results. Some examples of the effects of adopting an unsatisfactory method of local hardening have been brought to my notice, and in view of the misapprehension created, perhaps I may be permitted to give an explanation to your readers.

The oxy-acetylene blowpipe has long been employed for surface hardening by hand methods, but the difficulty in maintaining control of the hardening operation results in irregular hardening, which produces considerable variation in surface metal stresses, as is indicated in Fig. 1. To obviate these irregularities in surface hardening, the "Shorter" process of hardening was patented and developed in which a hardening machine gives that degree of precision in operation so necessary to obtain dependable results. These machines ensure uniform depth, area, and degree of hardening, as is indicated by the example shown in Fig. 2 which is surface hardened by this process.

Fig. 1.—Hand treatment stresses.

Fig. 2.—"Shorter" process condition by comparison

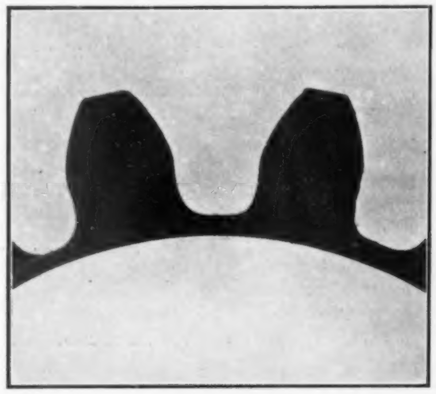

Fig. 3.—Uniform treatment by "Shorter" process (cross section).

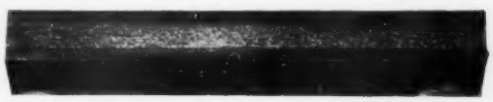

Fig. 4.—Uniform treatment by "Shorter" process (longitudinal).

This "Shorter" process has proved to be the most scientific method of direct local hardening of gears and other metal parts, since it obviates the development of opposing and irregular surface stresses by reason of the hardening so prevalent in the "hand" method, and which are always liable to cause failure in the surface material when subjected to varying service loads.

A gear wheel hardened upon the tooth flanks by the "Shorter" process will have a uniform width and depth of hardening, as illustrated in Figs. 3 and 4. The martensitic area is not interrupted by interposing stresses which usually occur in the hand method. Where there is variation in application of so intense localised heat, followed closely by a cooling stream and affected by a large body mass, variation in surface stresses is bound to result. It will, therefore, be clear that the hand method of control, which usually involves oscillating the intense heating cone of the blowpipe over the surface of the metal, has the effect of a double heating and quenching continuously going on throughout the operation.

This cannot take place in the "Shorter" process method, which is definitely mechanically controlled and progressive in one direction only throughout the operation.

The "Shorter" process should not be confused with the hand method of hardening, which is often spoken of as "flame" hardening, if disappointment is to be avoided. Only recently it came to my notice that an important metallurgist examined a surface hardening specimen gear, believing it to be a "Shorterized" job, and nearly two years elapsed before a mistaken impression could be corrected, because no reference had been made to the writer upon the results found. When at last the photographs (Figs. 5 and 6) came into his possession he was able

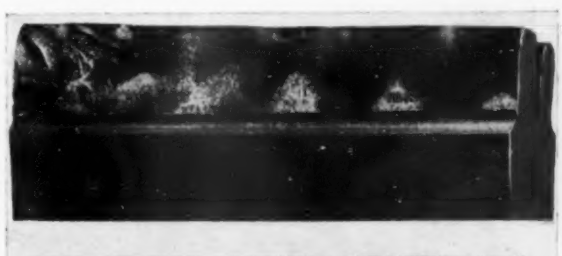

Fig. 5.—Two not unusual cases of hand treatment.

to show very clearly that the photographs were those of a hand or "flame," *but not a "Shorter" hardened job,* and the failure was clear evidence of the localised stresses set up by the hand method of treatment.

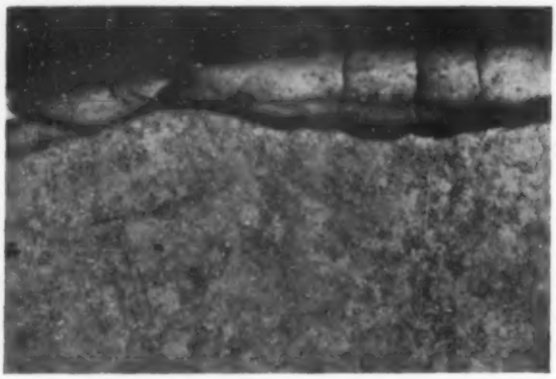

Fig. 6.—Result of irregular stresses created by hand treatment.

Compare these illustrations with the longitudinal section of a "Shorterized" gear tooth (Fig. 4), and the difference is self-evident; but a more practical demonstration of the utility and success of the "Shorter" method of surface hardening is clearly shown in the illustration, Fig. 7, which shows a pinion made in 0·5% carbon steel, and which, after "Shorterizing," was running in a London tramcar when, on account of an accident, it had to be removed.

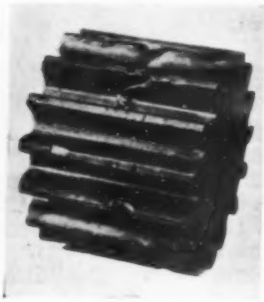

Fig. 7.—First "Shorterized" pinion damaged in accident.

It will be seen that a very destructive shock has been applied to this pinion without causing any fracture. Not a tooth failed; and the hardened zone was definitely crushed into the soft core of the tooth without even causing the slightest degree of flaking or separation of the hardening or martensitic area from the body of the teeth.

It requires no greater proof that hardening produced by the "Shorter" process is scientific in character and, therefore, satisfactory in service.

Electric Furnace Heating

(*Continued from page 2*)

of four clamping devices, the hydraulic plunger being lowered. The heating elements are arranged along the two longitudinal sides of the chamber. Temperatures of from 250° to 750° C. can be kept constant within ±5°. Sheets up to 17 ft. by 10 ft. can be annealed, the height of pile being up to 3 ft. With an annealing time of from 4 to 6 hours, about 40 tons of sheet can be annealed in 24 hours, the power consumption being less than 100 kwh. per ton. A non-oxidising atmosphere is maintained in the retort by the admittance of either carbon dioxide or nitrogen. When using nitrogen it is advisable to keep the oxygen content of the gas below 3%. Mechanical tests and micro scopical examination show that the two gases do not exert any detrimental effect upon the annealed sheets.

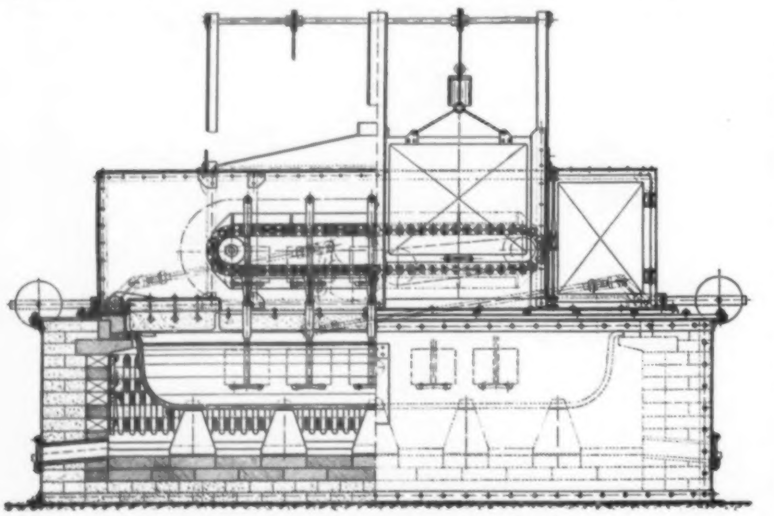

Fig. 6.—Automatic bath hardening furnace, effective in producing non-oxidised components.

Automatic Bath Hardening Furnace.

The salt-bath method of heating is effective in producing non-oxidised components, since all air is excluded from the surface of the charge during the time of heating, and the thin film of salt which adheres to the charge protects the surfaces from the air during its movement to the quenching bath. A recently designed furnace of this type maintains and accurately records hardening temperature, charging time, duration of heat, and discharging time; in addition, it eliminates rejects. This furnace, a section of which is shown in Fig. 6, is designed for hardening steel parts requiring high quality and uniformity of treatment. It provides for a high running output with low labour charges.

The components to be hardened are placed in jigs suspended from a conveyer chain, which automatically lowers them into the bath. Upon completion of the hardening, the finished parts are automatically raised from the bath while new jigs, which have been charged in the meantime, are immersed. The temperature of the bath is controlled by means of a thermocouple immersed in the bath, and a further couple placed adjacent to the heating elements, both temperatures being continuously recorded.

In continuous service this furnace has a capacity of casehardening from 45 lb. to 110 lb. of parts every 15 to 20 mins., the exact time depending upon the shape and size of the work and the number of pieces that can be simultaneously placed in the furnace. On an average, a daily output of 5,500 lb. of small parts can be dealt with. The weight of the jigs is purposely kept low, and this fact has a direct influence on the current consumption, which is about 140 to 200 watts per lb. of steel treated, including radiation losses and unavoidable waits between charges.

It should be noted that many of the features described in the foregoing article are the subject matter of patents in European countries. The manufacture and sale of "Russ" electric furnaces in England and the British Empire are controlled by G.W.B. Electric Furnaces, Ltd.

Maxilvry malleable stainless steel, a product of Edgar Allen and Co., Ltd., has just been tested to determine the effect upon it of cider. The tests were carried out by an independent body, and show conclusively that the resistance of this steel to the liquid in question was high, there being only a very small loss, 0·0008 grms. in the case of cider, with high malic-acid content (1%). In the case of cider with high tannin content there was no loss, nor was there any loss with a strongly acetified cider. No alteration in the flavour of the ciders took place.

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PURCHASING POWER and PROSPERITY.

ALTHOUGH the trade outlook is a little brighter, and a definite reduction in the unemployment figures is apparent, much more rapid progress is needed to mitigate, even in a small way, the distressing possibilities for thousands of people throughout the winter. Unemployment is exerting a depressing influence on all countries, and efforts to overcome it and to restore normal trade is the earnest desire of all governments. That the wastage of wealth during the great war is a direct cause there can be little doubt, but just as all problems at that time were subservient to anything that might assist the success of man and machines in military warfare, so now the primary object of all governments should be to concentrate on the unemployment problem by doing anything likely to terminate the present economic war.

Few will disagree with Mr. Archibald Gilchrist, who, in a recent address, said that the conditions at present ruling are so distressing that everybody feels poor, from the humblest in the land, who must find his responsibilities just now almost unbearable, to the more fortunate person who a short time ago considered himself as a possessor of wealth, but who has had to watch his holdings depreciate, quite unable to stay their fall. The fact that the world is better equipped to-day than ever it was, and that history records many periods of depression which were succeeded by periods of prosperity, is of small comfort to those in the toils of the present depression.

It is generally appreciated that the productive capacity of machinery was enormously increased during the war. The developments made during that time were probably greater than would have been effected in a decade under normal peace conditions, and, at the conclusion of hostilities, progress in production far outdistanced the development of the means of distribution. It should not be assumed, however, that machinery is the cause of the present distress, for there are still countless people without what we regard as the bare necessities of life. Actually, the consumer demand is not being met, because, cheap as machine-made goods are, there is a scarcity of money—an unemployed community lacks the power to buy. The high productivity of machines is being rendered abortive by the poverty of people and of nations.

Each nation is protecting its own industries, yet its manufacturers want to sell their products abroad, and in order to overcome the heavy duties that are imposed exact a higher price for their products from the home markets. Even though they may be producing for the home market only there is a tendency to exact a higher price for their commodities than would be possible if free and open competition with foreign products were allowed. Thus, there is a tendency for the cost of machine-made goods to be greater than it should be.

The buying power of a nation is represented largely by the working population multiplied by the average income. In the present depressed condition with average income at a very low ebb, it is hopeless to expect any demand to originate from this source, although once the demand has been created, as wages become earned it will be augmented by those earnings. Apparently the wheels of industry will only operate adequately when money becomes more plentiful or cheaper, thus enabling the peoples of the world to satisfy their requirements; but the restoration of confidence is also necessary. To raise prices artificially will certainly give a profit margin to the manufacturer if he sells his product, but if the power of nations to purchase is not increased then the product is made more difficult to buy.

It must be admitted that the need for goods, from a consumer's point of view, is quite acute, but as everybody's purchasing power is at its lowest ebb the demand remains unsatisfied. If by some means it were possible to create fresh purchasing power the flow of commerce would again accelerate. This, together with the need for freer exchange of commodities, seems to be the chief obstacle to the solution of the depression. Whether a solution will emanate from the deliberations at the coming World Economic Conference it is difficult to prophesy, but there is every reason to believe that now the election is over active steps will be taken by the United States to come into line with other nations of the world in seeking a common policy for righting the economic situation.

The return of the Democratic Party to power for the first time since President Wilson's day has a special influence on the situation, and it is natural that the interest for the world should centre on the question of what changes may be expected in the international policy of the United States. The most vital factor between America and Europe—that of war debts—was not an issue at the election, consequently forecasting the probable policy is difficult, but on the question of tariffs, another matter of great importance to other nations, it is possible to give some opinion, for President Roosevelt expressed the need for lowering the tariff wall round the United States. With tariffs, however, is linked up war debts and disarmament, and on all these questions the United States is in a position to give a lead to the World. If the English-speaking nations—Britain, America, and the British Dominions—would unite with the single purpose of setting the world on its feet again their combined influence would have a marked effect in unravelling the present economic situation. Given goodwill and understanding, that should not be impossible. We believe this to be the best hope for the recovery of a stricken world from the present distress which is bringing unhappiness and travail to so many people.

No action of this kind, however, is immediately possible, because the term of office of the old Congress does not expire until March, but definite action should be taken by the Governments of all nations with a view to the restoration of normal commercial operations. Such action as is taken can only act as a palliative, because no sound progress can be made until the main problems of tariffs and war debts are settled, but something must be done to alleviate the distress unemployment is causing, and since work in some form is the best solution all avenues must be diligently searched that are likely to give definite results. Any progress of this kind is dependent upon the restoration and maintenance of peace and goodwill, which fosters human evolution and increases confidence, which will tend towards the freer circulation of money and create that purchasing power for manufactured articles such as will enable production to reach the level to which it was previously artificially raised.

Dominion Markets for British Iron and Steel

Difficulties must be overcome to reap the benefits of the Ottawa Conference.

THERE is apparently general agreement that the British iron and steel industry cannot fail to benefit from the results of the Ottawa Conference, but it would be distinctly unwise to assume that a complete reversion from previous practice is likely to take place immediately. It is true that in the agreements the Dominions have afforded increased opportunities for imports of British iron and steel by the reduction of tariffs and the removal of restrictions, and a particularly encouraging feature of the arrangements for preferential treatment within the Empire was the spirit in which the Conference was conducted. The fact remains, however, that some time must elapse before a practical working understanding is achieved.

In many of the Dominions tariffs have been used to protect their own iron and steel industries, and the reduction of tariffs means that they have reduced their protection; evidently this has been done in the larger interest of promoting trade within the Empire. The increased preferences refer to selected manufactures in which the iron and steel industry is specially equipped to supply without injuring enterprise in any of the Dominions. But it can be reasonably expected that an increased interchange between the nations of the British Commonwealth will ensure increased commercial activity in the various Dominions which will result in increased buying from their own iron and steel manufacturers as well as from Britain.

Many difficulties will need to be overcome before British manufacturers will supply the majority of the iron and steel imported by the Dominions. In Canada, for example, close commercial relations have existed with United States iron and steel interests for years; the plants are relatively close, and orders can be despatched with little loss of time. Further, it should not be forgotten that many of the most important manufacturing plants using steel have been built by United States capital, and are accustomed to American specifications and quality. Canadian structural engineering is based on the specifications of the A.S.T.M., and although there would be little difficulty in modifying the structures to employ material of British specifications, difficulties will undoubtedly arise from mixed materials. Certain sizes and shapes will continue to be obtained from the United States because they are not rolled in this country. It is possible that new rolls may be installed to supply material shaped to the requirements of the Canadian market, but sufficient has been said to indicate that a rapid change in the policy of buyers of iron and steel materials is out of the question.

Canada is, of course, an exception in this respect, due to her United States connections, but to a varying extent difficulties of a somewhat similar nature will be encountered in extending the markets in other Dominions. From a purchasing point of view the iron and steel requirements of Canada are probably most important, for in 1931, a very lean year, rolled iron and steel imports totalled 517,716 tons, of which 21% (109,410 tons) was supplied from the United Kingdom, and 68% (353,094 tons) from the United States.

The Ottawa Conference has certainly given a stimulus to the iron and steel industry, but the benefits will only accrue slowly, and only by persistent efforts to understand each of the markets and by meeting requirements with the least possible delay. This can best be done by appreciating the difficulties and taking immediate steps to reduce them to negligible proportions. The degree of co-operation that has been established between representatives of the iron and steel industries in certain Dominions with those at home is an important step, for which the delegates are worthy of congratulations, and we believe that orders formerly placed with foreign countries will gradually be diverted and supplied by British manufacturers.

Forthcoming Meetings

THE INSTITUTION OF MECHANICAL ENGINEERS.

Dec. 2. Thomas Lowe Gray lecture: "Eight Years' Salvage Work at Scapa Flow," by E. F. Cox.

IRON AND STEEL INSTITUTE.

WEST OF SCOTLAND.

Dec. 9. "Fundamentals of Fuel Economy in Iron and Steel Practice," by E. C. Evans, B.Sc.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Nov. 25. "Rejuvenation of Ships and Their Machinery," by Andrew Hamilton, C.B.E.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Nov. 22. "Method in Ship Design," by S. B. Ralston.

Dec. 6. "Recent Developments in Diesel Engines," by R. Sulzer.

THE INSTITUTE OF METALS.

BIRMINGHAM SECTION.

Dec. 1. "Oil-fired Furnaces," by S. F. Unwin.

Dec. 15. "Welding of Copper," by H. Martin.

LONDON SECTION.

Dec. 8. "Some Aspects of the Selection of Engineering Material," by L. B. Hunt, A.R.C.S., M.Sc. (Joint meeting with the Institute of British Foundrymen.)

NORTH-EAST COAST SECTION.

Nov. 26. "New Demands on the Brass Foundry," by J. Arnott, F.I.C. (Joint meeting with Newcastle Branch of the Institute of British Foundrymen.)

Dec. 13. "Centrifugal Casting of Non-ferrous Alloys," by F. W. Rowe, B.Sc.

SCOTTISH SECTION.

Dec. 12. "Ageing and Age-hardening of Metals," by C. H. Desch, Ph.D., D.Sc., F.R.S. (Joint meeting with Institution of Engineers and Shipbuilders in Scotland.)

SHEFFIELD SECTION.

Dec. 9. "Degreasing and Cleaning," by W. F. Jesson. (Vapour cleaning.)

SWANSEA SECTION.

Dec. 8. "Some Industrial Pyrometry Problems," by Ezer Griffiths, D.Sc., F.R.S.

THE INSTITUTE OF MARINE ENGINEERS.

Dec. 13. "Experiences with High-pressure Steam Installations in the Royal Navy," by Eng. Capt. S. R. Dight, R.N.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM, COVENTRY, AND WEST MIDLANDS BRANCH.

Nov. 22. "The Magnetic Moulding Machine," by T. W. Bullock.

Dec. 8. "Some Experiences with the Balanced Blast Cupola," by H. H. Shepherd.

EAST MIDLANDS BRANCH.

Dec. 10. "High duty Cast Iron," by A. L. Norbury, D.Sc. (At Derby.)

LINCOLNSHIRE SECTION.

Dec. 3. "Cylinders for Steam and Diesel Engines," by F. J. Cook, M.I.Mech.E.

LANCASHIRE BRANCH.

Dec. 3. "Further Notes on Oil-engine Foundry Practice," by H. E. Beardshaw.

PRESTON SECTION.

Dec. 7. "Wages: Their Relation to Selling Prices," by W. A. Hudson.

MIDDLESBROUGH BRANCH.

Dec. 9. "A Few Experiences in Practical Foundry Work," by J. J. McClelland.

NEWCASTLE AND DISTRICT BRANCH.

Nov. 26. "New Demands on the Brass Foundry," by J. Arnott, F.I.C.

Dec. 15. "Nitricastiron—Cast Iron Suitable for Nitrogen Hardening," by J. E. Hurst.

SCOTTISH BRANCH.

Dec. 3. "Rotary Furnaces in the Foundry," by W. Scott.

SHEFFIELD AND DISTRICT BRANCH.

Nov. 18. "Mammoth Castings for the Cunarder building on the Clyde," by F. Swift.

Dec. 12. Discussion—Refractories (at the invitation of the Sheffield Society of Engineers and Metallurgists).

Dec. 16. "Steels for Steel Castings," by W. West.

Heat-treatment Furnaces and Equipment

Steady improvement in designs of electric apparatus are reflected in a recent exhibition and demonstration of electric furnaces at Sheffield.

CONSIDERABLE progress has been made in recent years in every branch of electrical engineering. The results of continued research and invention, together with steady improvement in design, are reflected by the increasing size, efficiency, and adaptability of electrical apparatus of all kinds. The services rendered by electricity are more numerous, and are discharged more effectively than ever before. Much of this development can reasonably be credited to various municipal electricity supply departments for the iniative displayed in giving facilities for showing the possibilities of suitable appliances and equipment. An illustration of this is the exhibition and demonstration of electric heat-treatment furnaces and equipment organised by the electric supply department of the City of Sheffield, and held at Sheaf Street Works on November 7–11. Those who visited this exhibition will appreciate the extent to which these undertakings are facilitating progress.

The furnaces on view represented the latest developments of Wild-Barfield Electric Furnaces, Ltd., and included both vertical and horizontal types of automatic hardening furnaces, specially designed furnaces for general heat-treatment, tempering, general purposes, and high-temperature service, as well as a variety of laboratory muffle furnaces. Considerable interest was taken in the exhibits, and well-known firms in the Sheffield area supplied parts to enable the furnaces to operate on a production basis,

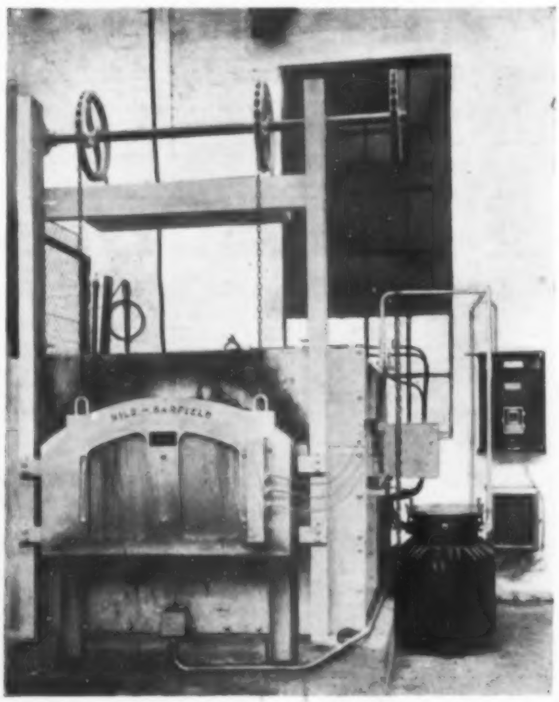


Fig. 1.—Box-type general heat-treatment furnace with wide appliations.

and the results achieved indicate that the demonstrations have served a very useful purpose.

The horizontal and vertical types of hardening furnaces shown determine the exact moment when tools or parts in carbon-carburised and low-alloy steels should be quenched. This is possible by means of the electric-magnetic device which is incorporated with these designs, by which the work is magnetised while it is being heated. Immediately the temperature is such that the work becomes non-magnetic, an indicator on the switchboard informs the operator, and the charge is quenched. By this method the most suitable structural condition for maximum hardness, toughness, and resistance to wear is obtained.

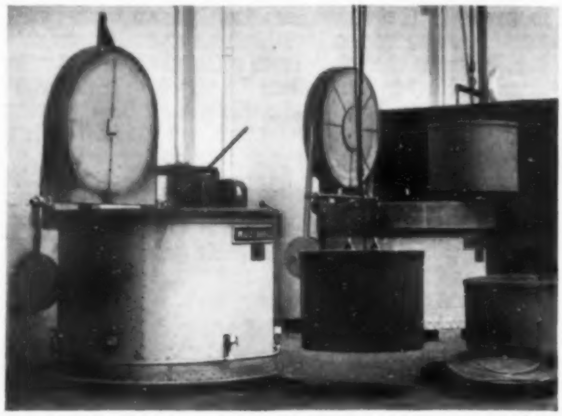


Fig. 2.—Arranged with forced air circulation, this furnace is suitable for low-temperature operations.

A large box-type general heat-treatment furnace suitable for carburising, refining, hardening, normalising, and annealing of steel parts, vitreous enamelling and other operations, attracted much attention. This type of furnace, which is illustrated in Fig. 1, can be built to any required size. It is fitted with standard heating elements of the hairpin type, and is suitable for temperatures up to 1,050° C. Uniformity of temperature and close control render it suitable for accurate heat-treatments. Much attention is given to insulation to effect economy in use.

Whenever work is heat-treated at comparatively low temperatures, such as tempering carbon or high-speed steel parts, the heat-treatment of aluminium alloy and similar operations, it is important to ensure that the work is uniformly heated. A recently designed furnace suitable for these operations is shown in Fig. 2. It is arranged with forced air circulation. The air is driven by a centrifugal fan over the heating elements and drawn down through the cold work which has to be heated. In heating the work the hot air is cooled immediately about it, and a great difference is recorded from the temperature of the air on leaving the heating elements. Gradually, however, as the charge absorbs heat, the difference becomes less marked, and when the temperature coincides the work is ready for removal. Incorporated with this furnace is the Wild-Barfield-Foster patent charge progress recorder, which not only records the temperatures of charge and air, but also automatically controls the temperature.

The several laboratory furnaces shown had a special appeal to works chemists and metallurgists, since close control, uniformity of temperature, and compact design, claimed to be amongst the advantages of these furnaces, meet a special need. Included amongst the exhibits was a hardness testing machine and a works projection microscope, while samples of the casehardening compound "Eternite" and the open-hearth compound "Kleenard" were available.

Molybdenum-Manganese Alloy Steels

By W. F. Rowden,

Technical Department, High Speed Steel Alloys Ltd., Widnes.

The use of costly alloy steels for constructional details is not always justified, and but few steels offer the engineer a half-way choice between carbon steels and high alloy steels. Recent developments with molybdenum-manganese steels, however, which are discussed in this article, will do much to solve the problem.

THE use of carbon steel for constructional details in a large number of engineering industries is becoming more and more limited. Many factors are responsible for this gradual change ; the development of the high-efficiency car, for instance, has necessitated a demand for the transmission of increased power without increasing the total chassis weight. Another striking example is afforded by the machine-tool industry. Before the advent of the special alloys now in use cutting speeds were low, and it was then quite possible to build a machine tool in which the principal parts were of plain carbon steel. Now, however, cutting operations are performed at speeds formerly considered to be impossible, and in order to withstand the great increase in stresses and wear, it is found necessary to depart from the well-tried carbon steels. Numerous examples of this general speeding up will at once be apparent in other branches of engineering.

For some high-duty purposes where weight is cut down to a minimum, designers and engineers turn at once to the higher alloy type of steel of the molybdenum-nickel-chromium class, the properties of which are too well known to discuss here. There are, however, many applications where the use of these steels is not justified, either because of the high cost or because the highest physical properties are not required.

Until the recent development of the steels about to be discussed, there were very few steels in existence which offered the engineer a half-way choice between the carbon steels and the high-class alloy steels containing two, three, or more alloys involving considerable expense.

What may be termed the first elementary alloy steel is that known as the carbon-manganese steel. This steel is of ordinary carbon content, but carries additional manganese to the extent of a total content of around 2·0%. As a constructional steel this composition has many advantages over a carbon steel of similar carbon content. In the heat-treated condition a considerable increase in yield-point is recorded, together with a higher yield/tensile ratio ; these higher physical characteristics are not obtained with any undue sacrifice of ductility. What is, however, perhaps the most important advantage, is the high notched bar or Izod impact values obtained. The Izod impact test is now being realised as of the highest importance, as it affords a very good indication of the resistance of the steel to impact and alternating stresses. It is also held by some authorities as affording some means of gauging a steel's resistance to fatigue.

The carbon-manganese steel, therefore, does fill a definite place in constructional steels. Its use, however, is confined to small sections, as complete hardening in larger sections cannot be obtained. In addition, this steel, as commercially manufactured, is a distinctly temper-brittle steel, which means that, if tempering stresses are to be avoided, cooling from the tempering heat must be carried out slowly, so producing a low impact test.

The conditions are similar to those ruling in the case of the nickel-chromium steels. Here a most excellent range of properties can be obtained, but, unfortunately, the steels are subject to temper brittleness, which decidedly limits their usefulness. The addition of small percentages of molybdenum, in the majority of cases 0·40%; is quite sufficient to make these steels entirely non-temper brittle. The effect of molybdenum in overcoming temper brittleness is illustrated in Fig. 1, from which it will be observed that the impact values in the case of the molybdenum steel are the same, irrespective of the rates of cooling from the tempering temperature.

Investigations with this alloy in the carbon-manganese steels show that here again the influence of molybdenum is precisely the same. Burns[1] gives the following figures as showing the influence of even a small percentage of molybdenum in an acid open-hearth steel of the following composition : Carbon, 0·35% ; manganese, 1·30%, which without molybdenum gave impact figures of 35 ; 15 to 20 ; and 15 ft.-lb., after tempering and cooling in water, air, and furnace respectively. With an addition of 0·16% molybdenum, the impact figures were 53, 50, and 53 after cooling in exactly the same manner from the tempering temperatures. Increasing manganese content has the

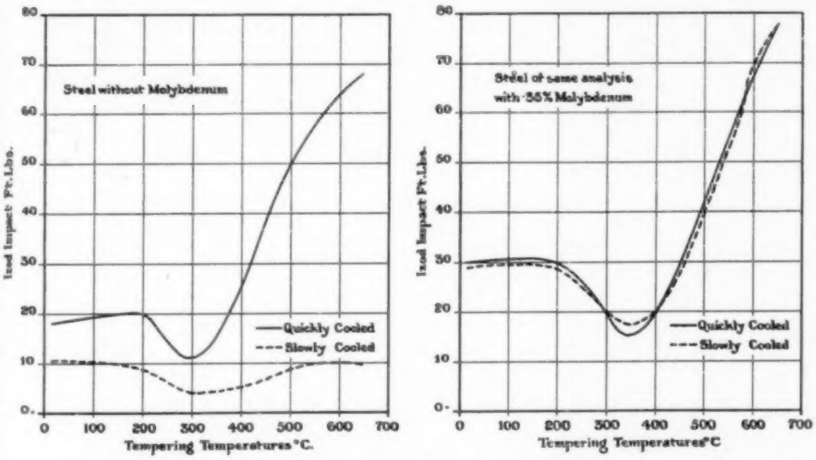


Fig. 1.—Comparison showing the effect of molybdenum in overcoming temper brittleness.

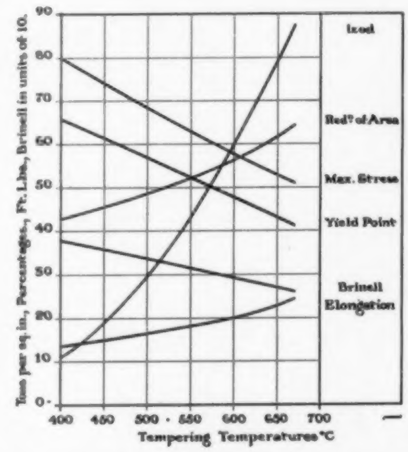


Fig. 2.—Physical properties obtainable on 4½ in. diameter bar of molybdenum-manganese steel.

1 Burn. *Journal of the Iron and Steel Institute*, 1931. No. 11, page 241.

effect of increasing susceptibility to temper brittleness. Greaves and Jones[2] give data relating to a 0·36% carbon, 2·24% manganese steel, which, after oil-hardening and tempering in water, gave impact figure of 74 ft.-lb., but when cooled slowly only 4 ft.-lb., a susceptibility ratio of 18·5 to 1. An addition of 0·52% molybdenum to a steel of similar carbon and manganese contents had the effect of reducing this ratio to 1·2 to 1.

Steel manufacturers also confirm that, from the point of view of temper brittleness the molybdenum-manganese steels are quite free from this complaint, so that, irrespective of the rate of cooling from the tempering temperature, consistent impact figures are obtained. Slow cooling can therefore be adopted, which in turn ensures relief of hardening stresses, and considerably simplifies heat-treatment, as well as avoiding distortion due to quenching.

With regard to the physical properties of the molybdenum-manganese steel, these naturally vary to some extent according to the analysis. They are produced in general in two grades: (1) With carbon content of 0·15% to 0·20%; and (2) 0·20% to 0·30% carbon; manganese content in each case lies between 1·4% to 1·70%, whilst molybdenum is between 0·20% to 0·40%. 650° C. In common with other alloy steels, the best range of physical properties is secured between these two temperatures.

A mass graph for a steel of somewhat lower carbon content of 0·15%, but with 0·25% molybdenum and 1·61% manganese, is illustrated in Fig. 4; naturally, with the carbon content being lower than in the first case, the maximum stress is also somewhat reduced. This steel meets the demand for a material giving maximum stress up to 45/50 tons per sq. in., the heat-treatment in this case being oil-hardening and tempering at 650° C.

In both these types of steel oil-hardening may be replaced by water-hardening if the section is uniform, when a higher range of physical properties will be obtained in the tempered condition. Where facilities for hardening do not exist, or the dimensions of the parts do not readily lend themselves to oil- or water-hardening, excellent results can be obtained with this lower carbon type of steel when normalised and tempered. Fig. 5 shows properties obtained on bars up to 4¼ in. diameter after normalising at 850° C. and tempering at 600° C.

The manufacture of these various types of molybdenum-manganese steels is much simpler than the high alloy

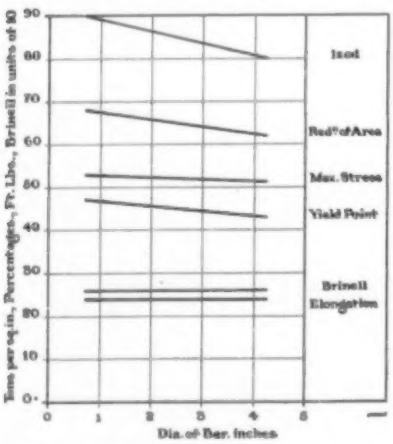


Fig. 3.—Composition graph showing physical properties of bars of varying diameters.

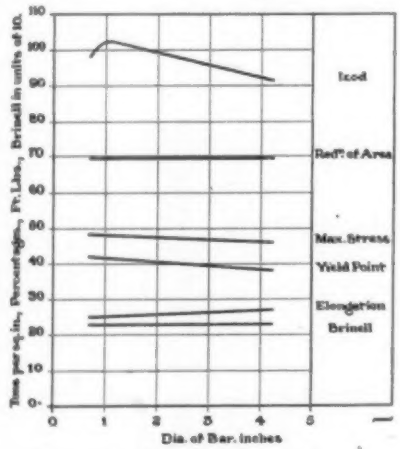


Fig. 4.—Similar graph from bars the steel of which has a lower carbon content.

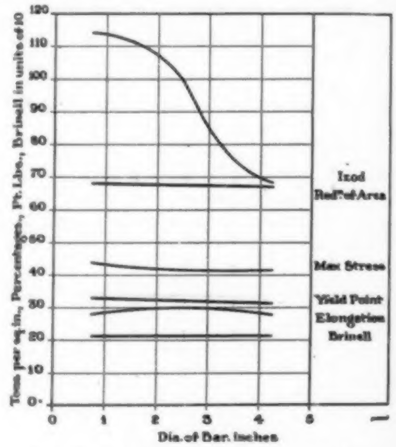


Fig. 5.—Properties of this lower carbon type of steel when normalised and tempered.

Molybdenum additions to the normal carbon-manganese steel show a progressive increase in physical properties in direct ratio to the molybdenum content. For similar maximum stress, in comparison with steel without molybdenum, the yield-point and elastic limit are increased together with an increase in elongation and reduction of area, and a remarkable increase in the impact value, whilst for equal ductility the maximum stress, yield-point, and elastic limit are increased, and at the same time an increase in the impact value is given.

An important feature of this steel is the effect of section or mass on the physical properties. Fig. 2 shows the physical properties obtainable on 4¼ in. diameter bar after water-hardening at 850° C. and tempering as shown, the analysis of the steel being C 0·30%, Mn 1·75%, Mo 0·18%. Fig. 3 is a composite graph of physical properties obtained on bars of 11/16 in. to 4¼ in. diameter after oil-hardening and tempering at 650° C., from which it will be noted that as the section increases there is very little fall in the physical properties. For an alloy steel of low alloy content the properties obtainable on a 4¼ in. diameter bar compare very favourably with many steels of considerably higher alloy contents, and naturally considerably greater cost, an impact figure of 80 ft.-lb. associated with a tensile of 52 tons in the oil-hardened condition and tempered, being quite an achievement of merit. Steel of this analysis is intended to be used for maximum tensiles of 60 tons, which indicates a tempering temperature between 550° and

content steels. As is well known, certain precautions have to be taken throughout the melting, casting, and subsequent operations of the latter if defects are to be avoided The manufacture of the molybdenum-manganese steels, on the other hand, follows good carbon steel practice. The molybdenum is added in a convenient form to suit the particular melting process, and is, of course, recoverable in returned ingot scrap, etc. In addition, the extra cost due to molybdenum is small, as only fractional percentages are required to achieve the desired results, whilst the additional manganese is negligible in cost.

In forging and stamping, practice follows that of a carbon steel—after these operations the part can be thrown on the floor to cool without any precautions being taken against cracking; these factors and simplified heat-treatment all make for cheaper production. A point of importance is the machining qualities of the steel in the heat-treated condition, by virtue of the fact that as the alloy contents are low, machining can be done at speeds approaching that of a carbon steel. This property may not be of importance where modern cutting alloys are in use, but is of value where ordinary high-speed steel is employed.

In conclusion, the molybdenum-manganese steels meet the requirements of the modern engineer, who requires steel of medium strength, with the improved properties characteristic of the more costly alloy steels, and working qualities comparable with those of carbon steels. The author desires to express indebtedness to the English Steel Corporation, Ltd., for their kind permission to reproduce data relating to physical properties and effect of mass.

2 Greaves and Jones. R.D. Report. *Journal of the Iron and Steel Institute*, 192[illegible], No. 1, page 251.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XIV.—Cold-Rolling Mills.—Contd.

Multiple-roll Mills.

Multiple-roll mills include those fitted with more than two rolls to a stand. The principal classes of multiple-roll mills are the three-high, four-high, cluster, and Steckel types. Three-high mills are employed for slabbing and running-down stock for the production of aluminium coil, and are well adapted for some operations. They may also be used for certain finishing operations. As is well known, backed-up mills have been coming into use rather rapidly of recent years for rolling various metals and alloys, chiefly steel, nickel, and brass. Four-high mills have only lately received serious consideration in aluminium practice. It appears to the writer that they may find application for both roughing and finishing aluminium in the form of broad strip as well as for the processing of duralumin and other hard alloys in various widths. This statement applies also to cluster mills. That backed-up mills can be used to advantage for rolling a soft metal like aluminium in narrow widths has not been demonstrated to the satisfaction of some operators and mill builders. The Steckel mill is a special type of four-high mill in which coil is drawn between the small working rolls by means of power-operated reels (winding drums). Recent experiments have indicated that the Steckel mill has important possibilities as a run-down and finishing mill for long coil.

Brief descriptions of the several types of multiple-roll mills are given in the following paragraphs, and their applications in aluminium-rolling practice are indicated.

Three-high Mills.—The three-high mill consists of three superimposed rolls suitably mounted in a housing. Drive is by individual motor through a reduction unit. The top and bottom rolls are of the same diameter, and ordinarily the middle roll is of smaller diameter. In rolling, the stock is passed between the top and middle roll in one direction and between the bottom and middle roll in the opposite direction. The material is handled on suitable work tables mounted on each side of the mill. These tables lift or tilt and are put in proper position to feed or receive the stock according to the direction of passing. Three-high mills are built in various sizes according to requirements. The largest unit in operation has rolls measuring 44 in. (top and bottom) and 28 in. (middle) in diameter by 144 in. in face length. This was built recently by Schloemann Aktiengesellschaft, Düsseldorf, Germany. Fig. 8 shows a view of a large three-high mill by Engelhardt Achenbach sel. Söhne, Buschhütten, kr. Siegen, Germany; the rolls measure about 84 in. in face length. This mill was constructed for the hot and cold rolling of hard aluminium alloys like duralumin.

The construction of three-high mills varies considerably among the different builders. Methods of driving and of making roll sets present the chief variations in design. In some cases the middle roll is held in a fixed position, and the top and bottom rolls are movable up and down by screws. In other designs, the bottom roll is held in fixed position, and the top and middle roll are adjustable. All rolls are positively driven, either by spindles or through gearing. General design as regards housings, spindles, rolls, screws, pinions, etc., and material of construction are the same as those previously described in this article for other types of mills. Tables may be equipped with loose or power-driven rollers and are mechanically actuated.

An idea of the construction of three-high mills may be gained from the following description of equipment built by Sundwiger Eisenhütte Maschinenbau-Aktiengesellschaft, Sundwig, kr. Iserlohn, Germany. The rolls are spindle driven, a special sliding coupling being used in connection with the drive of the middle roll. Roll bearings are made in three parts and are adjustable. The separate pieces can be removed from the outsides of the housings. Lubrication is by means of a pressure pump which forces grease to several points of the bearings. The counterbalancing of the top roll is effected by means of main springs working in conjunction with auxiliary springs. With this arrangement, the top roll with bearing, breaker plate, and screw, are pushed upwards with uniform pressure. The counter-

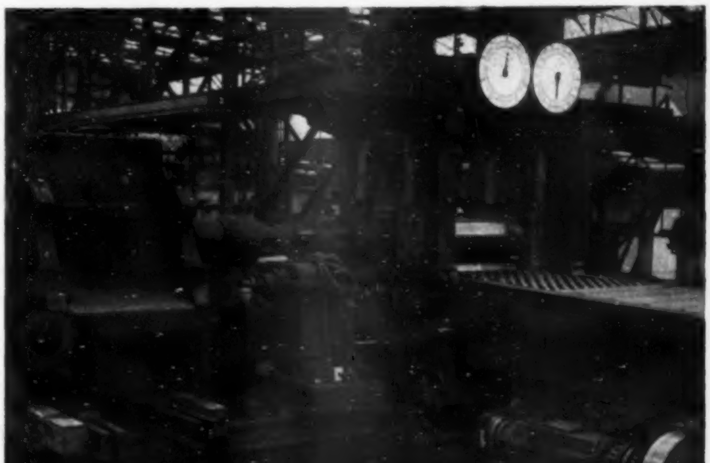


Fig. 8.—Three-high aluminium rolling mill (Engelhardt Achenbach sel. Söhne).

balancing parts are arranged on the roll housing. The middle roll is counterbalanced by weights arranged laterally under the lifting table. All parts of the balancing and adjusting arrangement of the middle roll are accessibly disposed on the bedplate. Screws are driven by worm-gears, the worm-gearing being fitted on the housing. The driving gear of the screw spur wheels, together with its coupling and motor, is mounted on a separate frame above the pinion housing. Separate handwheel adjustment is provided. The table arrangement consists of a tipping table in front of the mill and a lifting table behind it. The tables are made of steel sections and fitted with interchangeable rollers. Raising and lowering of the tables is effected by rods and levers actuated by a crank and worm-gearing through an electric motor. Control is by push button. The knock-off at the terminal positions is automatic.

Reference has previously been made to the large three-high mill built by Schloemann Aktiengesellschaft. This has been described by Pfann.[6] The housings and chocks

6 E. Pfann, "Modern High-Efficiency Machinery for the Manufacture of Non-Ferrous Metal Products," *The Metal Industry* (London), vol. 38, 1931, pp. 83–86; and "Neuzeitliche Walzwerke für Nichteisenmetalle," *Zeit. fur Metallkunde*, vol. 22, 1930, pp. 391–392.

of the roll stand are made of cast steel. Drive is by two 3,000-h.p. direct-current motors through a reduction unit. A special coupling with safety device connects the speed reducer and the pinion stand. The pinion housing is enclosed, and separate oil lubrication is provided for the pinion teeth and bearings. The bottom roll is driven by means of a universal spindle, spring mounted. A compound spindle is used for driving the top roll. This compound spindle can be thrown out of gear by means of a hydraulic device, when it operates as a friction spindle. The spindle can be thrown in and out of gear while the mill is operating. Drive of the middle roll is effected by means of gears and a friction spindle. A special roll-changing device is provided by means of which the rolls with chocks can be moved in and out of the roll stand from one side. Tilting tables, 30 ft. long, are arranged on each side of the mill. These are equipped with Schulte motor rollers, the peripheral speed of which can be accurately adjusted to suit variable rolling speeds. Lubrication of the roll-neck bearings is by means of a central greasing

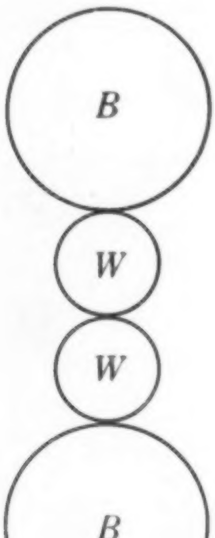


Fig. 9.—Arrangement of rolls in four-high mill.

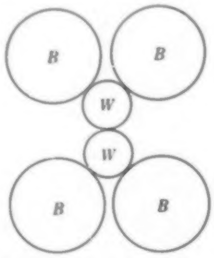


Fig. 10.—Arrangment of rolls in a cluster mill.

system. Indirect cooling is provided for the roll necks. Total weight of this mill, including drive, pinion stand, couplings, roll housings and rolls, and tilting tables, is about 1,000 tons. This mill has been built for an American company and is designed for use in both hot and cold rolling aluminium and duralumin.

Small- to medium - size three - high mills have been employed for various rolling operations on aluminium in European plants, but have not come into general use in the United States.

Four-high Mills.—The four-high mill consists of four superimposed rolls mounted in a stand. In the arrangement, the top and bottom rolls are the backing-up and supporting pair, and the two middle rolls are the working pair. The diameter of backing-up rolls is two to three, or more, times that of the working rolls. Fig. 9 is a sketch of the arrangement, in which *B* and *B* are the backing-up rolls and *W* and *W* are the working rolls. The stock is passed between the rolls marked *W*. A four-high mill is shown in Fig. 7 of the previous article of this series (Part XIII.). Four-high mills are built in various sizes, having rolls up to about 72 in. in face length; the working rolls are from about 4 in. to 20 in. in diameter, and the backing-up rolls are up to about 48 in. in diameter. A sizeable mill is fitted with rolls 14 in. and 32 in. in diameter by 48 in. long.

Both non-reversing and reversing four-high mills ear built. The former may be installed as single units or set up in a tandem of, say, four stands.

One feature of the four-high mill is that the heavy backing-up rolls prevent flexure or springing of the small working rolls, thereby ensuring uniformity of gauge in wide strip. Another feature is that, in using small working-rolls, the arc of contact (with the metal) is greatly reduced from that formed on ordinary two-high mills fitted with rolls of normal diameters for given lengths. Rolling with a small arc of contact is advantageous, as compared with a large arc, in that much heavier reductions can be taken per pass or a given total reduction can be made with few instead of many passes. As an example, an instance may be cited where it required about 60 passes to reduce hard metal 35% on a two-high mill, but only five passes were necessary in accomplishing the same result on a four-high mill. In rolling, the smaller the diameter of the rolls the less is the amount of hardening of the metal for a given percentage of reduction. The net practical result of rolling with a small arc of contact is that hard metals and alloys can be run down rapidly with relatively few passes. Hence, the troublesome and expensive intermediate annealings,

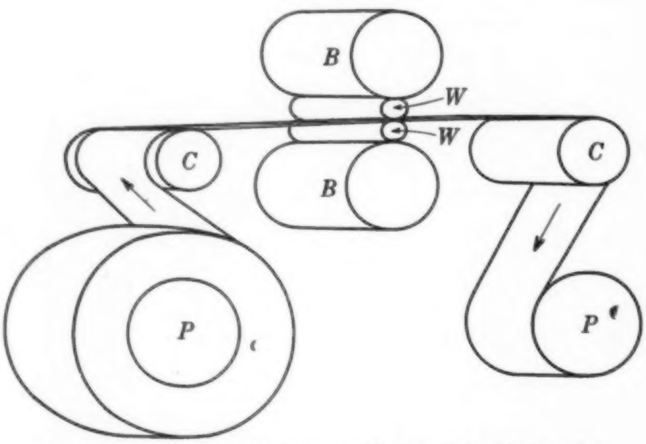


Fig. 11.—Arrangement of components in a Steckel mill (after The Cold Metal Process Co.

such as are normally required in processing on two-high mills, are eliminated, or at least the number is greatly reduced, when hard stock is run on four-high mills. Of course, 99+% aluminium can be drastically cold worked without annealings between passes, but this is not true of duralumin and related hard alloys.

In four-high mills the necks of the backing-up rolls are usually mounted in roller bearings. According to Jones,[7] the successful operation of a backed-up mill does not depend on roller bearings; wide strips have been rolled on mills fitted with ordinary bronze and babbitt bearings. However, it is evident that the power consumption is greatly reduced by the use of roller bearings. The working rolls of the four-high mill are not full floating as is the case in the cluster type. Hence, in the former, side and end thrust must be taken care of by bearings in order to hold the rolls in alignment. Both journal bearings and roller bearings have been used for the necks of working rolls of four-high mills. The drive of four-high mills is through pinion stand and spindles to the small working rolls. Four-high mills are operated at various speeds depending on the material rolled and the drafting; such mills have been run at 400 ft. to 600 ft. per min. on brass strip.

The four-high mill may be used to advantage in processing broad strip in aluminium and various alloys, and for strip of all widths in duralumin and hard alloys.

Cluster Mills.—The cluster mill is a six-roll mill, consisting of two superimposed working rolls of relatively small diameter, each supported and backed-up by two

7 L. Jones, "Backed-up Mills for Continuous Rolling," *Min. and Met.*, vol. 9, 1928, pp.133-135.

rolls of relatively large diameter. Fig. 10 is a sketch which shows the arrangement of rolls in a cluster mill; the rolls marked *W* are the working rolls, and those marked *B* are the backing-up rolls. As in the four-high mill, deflection of the working rolls in the cluster mill is prevented by the backing-up rolls. No bearings are required for the working rolls of cluster mills since these rolls are full floating, being confined by the backing-up rolls. Aligning bearings are, however, used in some mills. The necks of the working rolls are not used for supporting purposes but are connected to the spindles on one side for the drive and on the other side serve as water passages. Internal water cooling may be provided, and is usually advisable, for the working rolls of both four-high and cluster mills. The necks of the backing-up rolls in the cluster mill are normally mounted in roller bearings. Water cooling of the necks of backing-up rolls mounted in roller bearings is not required since the necks do not become hot. In the old-type cluster mills

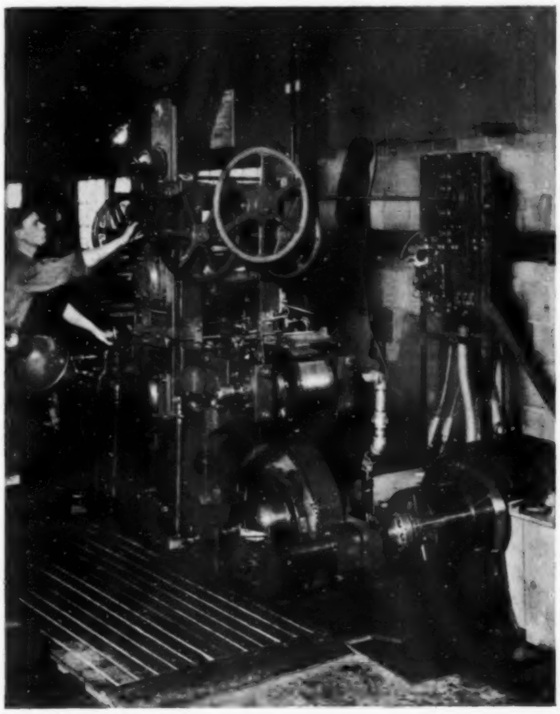


Fig. 12.—View of a small Steckel mill (The Cold Metal Process Co.).

the backing-up rolls were run in bronze journal bearings. Such mills were operated in Germany and Switzerland, and it was found that the bearings ran hot and did not work satisfactorily.

The advantages of the cluster mill are the same as those of the four-high mill, as above mentioned. Little information is available regarding the performance of the cluster mill in aluminium work, but its possible field of application is evidently the same as that of the four-high mill. Cluster mills are built in about the same sizes as four-high mills. Cluster mills supplied by E. W. Bliss Co., Salem, Ohio, have been built with rolls measuring from 4 in. to 72 in. in face length, the diameters being suitably proportioned.

Weiss[8] has recently discussed the application of backed-up mills in non-ferrous rolling.

Steckel Mills.—The Steckel mill is a four-high mill, fitted with small working rolls supported by large backing-up rolls. Neither the working rolls nor the backing-up rolls are driven, but the strip is drawn back and forth between the former by means of power-operated winding drums. The principle of operation is illustrated by the sketch in Fig. 11. Here *B* and *B* are the backing-up rolls, *W* and *W* are the working rolls, *C* and *C* are cooling drums, and *P* and *P* are power reels. The reel at the left is shown loaded with a coil, and the one at the right is empty—just starting to wind. Fig. 12 shows a view of a small Steckel mill.

As is evident, the working rolls act as a sort of die through which the strip is drawn as wire is drawn on a bench. Steckel mills are high-speed machines, rolling at the rate of 1,000 ft. to 1,400 ft. per min. They were introduced for the fast and accurate cold finishing of steel strip. Steckel mills are manufactured by the Cold Metal Process Co., Youngstown, Ohio.

Some tests were made recently with the view to determining the performance of the Steckel mill in running-down aluminium coil. The rolling was done on a mill fitted with rolls 20 in. in face length; the working rolls were 6 in. in diameter. Coil, 15 in. wide and 0·1 in. thick, was run down to 0·015 in. thick. The coils weighed about 175 lb. In the tests the number of passes was varied from 4 to 13, with suitable adjustment in the drafting. Very uniform gauge was produced. In one test the stock was run down from 0·1 in. to 0·015 in. thick with five passes; the time consumed in the operation was 8 min.

The results of these tests indicate that the Steckel mill can be used to good advantage for finishing aluminium coil. In production practice, larger coils should be fed than those used in the tests. Aluminium coils weighing 500 lb. to 1,000 lb. might be handled on a Steckel mill. Economy of operation requires the rolling of long lengths.

(To be continued.)

8 L. Weiss, "Die neuere Entwicklung der Walzwerke für Nichteisenmetalle," *Zeit. f. Metallkunde*, vol. 23, 1931, pp. 73–76.

New British Chemical Standard Cupro-Nickel "A."

Headquarters announces a new non-ferrous standard cupro-nickel having the following analysis:—

	%		%
Copper	68·85	Magnesium	0·027
Nickel	30·08	Carbon	0·02–
Silicon	0·12	Sulphur	0·01–
Manganese	0·89	Lead, not above	0·01–
Iron	0·05	Cobalt, not above	0·01–

This sample will serve as a standard for the analysis of cupro-nickel sheets and strip referred to in the British Standard Specification No. 374/1930.

It may be used also for checking the analysis of the following cupro-nickel alloys:—Condenser tubes, bullet envelopes, coinage, electrical rheostats and resistances, base metal thermocouples, domestic utensils.

It is believed that this is the only standard of its kind issued in either Great Britain, U.S.A., or the Continent, and it is, therefore, likely to be of international interest.

As usual the standard turnings have been analysed by a number of chemists representing the different interests involved, viz., independent analysts, government departments, railway chemists, cupro-nickel manufacturers and users.

The standard is issued in bottles containing 500 grms., 100 grms., and 50 grms., and each bottle is provided with a certificate showing the detailed analysis of each chemist together with an outline of the methods used. It is issued at a price which is estimated to eventually cover the cost, and may be obtained from Ridsdale and Co., British Chemical Standards Headquarters, 3, Wilson Street, Middlesbrough, or from laboratory furnishers.

In view of the increasing demand for the smaller sizes of electrically heated muffle, crucible, and high-temperature furnaces, Wild-Barfield Electric Furnaces, Ltd., have recently published an attractive brochure giving particulars regarding some new models covering general purpose furnaces, furnaces for melting lead and solder, and soldering-iron heaters. Particulars of laboratory tube furnaces, "Pyromic" nickel-chrome wire, pyrometers, and automatic temperature-control appliances are also given. Copies are available on application to Elecfurn Works, North Road, London, N. 7.

Steels for Casehardening

By FRANCIS W. ROWE, B.Sc., M.I.M.M.

The range of casehardening steels in common use are discussed, and factors which influence their physical characteristics are considered.

THE last two or three years have seen considerable clarification in the position as regards casehardening steels, although the process of standardisation and unification is by no means complete. Beyond the special steels employed for casehardening by means of nitrogen, the number of steels generally used now number—or ought to number—no more than four or five. For anything except very specialised duties or designs one or other of four or five grades of steel will successfully meet the service conditions. This is naturally all to the good, as it enables both the steel-maker and the purchaser to take advantage of mass-production conditions, and gives the many other benefits of a standardised product.

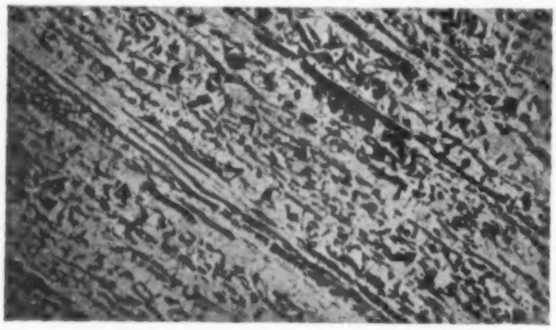


Fig. 1—Typical microstructure (longitudinal section) of high sulphur type free-cutting casehardening steel. Magnification 50 dias.

For relatively unimportant duties, where the main requirement is a hard exterior to the part, and where no particular heavy surface loading is to be experienced, and where the case has not to undergo repeated shock loads, the straight low-carbon casehardening steel is used. Due to the limitations of this material as regards core strength (and thus ability to withstand high surface loads), and the comparative brittleness of the case, this quality of steel is rapidly being displaced by the other grades, particularly in automobile and aero engine practice. An alloy steel, however, would unnecessarily increase the cost and for many duties give no corresponding service advantages; consequently the use of carbon casehardening steels for certain classes of work is likely to persist.

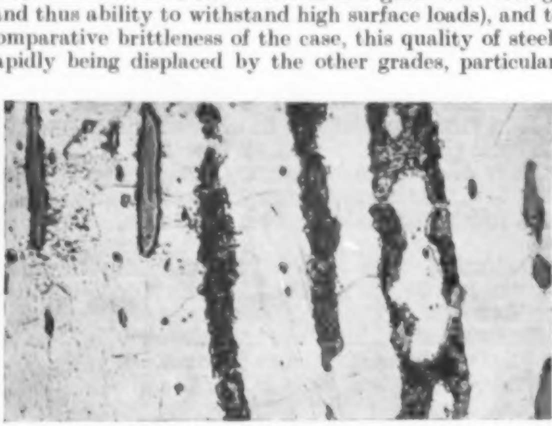


Fig. 2—Similar to Fig. 1, but at a magnification of 500 diameters, showing the elongated manganese sulphide inclusions and segregated pearlite.

Whilst basic open-hearth steel of good quality in this grade gives quite good results, there is little doubt that acid open-hearth steel is, in general, more satisfactory. This is shown, from supplies over a range of sources, in better casehardening properties. The case responds better to quenching in a good acid steel, there being less tendency for soft spots and imperfectly hardened patches to appear. With heavy sections, particularly parts with recesses, or where the quenching arrangements are not ideal, the basic low-carbon steels are prone to give trouble, especially if the steel has been "killed" with aluminium.

The material generally used has a carbon content of 0·12 to 0·16%, with manganese from 0·60 to 0·80%, and sulphur 0·060% maximum. For very delicate work the carbon content may be as low as 0·09%, but for anything approaching heavy sections (say, 0·75 to 1 sq. in.) such a low carbon results in low core strength and consequent inability of the case to withstand loads or influences likely to cause cracks It will be appreciated that the casehardened part is duplex material, and that the wider the difference in physical properties between the case and the core the more likelihood there is of the heating and cooling effects causing cracking or partial exfoliation of the case.

All those who have handled casehardened parts through such operations as grinding and straightening will have noticed the greater tendency for cracking to occur with low-carbon steels as compared with alloy steels. This, in a large measure, is due to the greater difference in hardness between case and core, but is also influenced to some degree by the greater toughness of the alloyed case.

One of the disadvantages of the low-carbon casehardening steel is that grain growth is more rapid than in the alloy steels. Therefore, with the normal carburising temperatures which are employed to give reasonably economical penetration—namely, 900°–920° C.—sufficient grain growth takes place in the core, even with case depths of only 0·040 in., as to necessitate a refining treatment (at a high temperature) for the core prior to final hardening. This—apart from the expense—causes extra distortion.

As will be seen later, with most alloy steels a single quench after carburising is, with case depths up to 0·040 in., sufficient to refine the core and give mechanical properties very nearly the maximum obtainable.

Free-cutting Casehardening Steels.

Before leaving the question of carbon casehardening steels, mention must be made of the free-cutting casehardening steels. These steels are so named because, due to a particular and regulated structure, they machine more readily than the normal carbon casehardening steels

TABLE I.

Typical Physical Tests on Low Carbon Free-cutting Casehardening Steel After Treatment.

Direction of Test.	Yield-point, Tons per Sq. In.	Max. Stress, Tons per Sq. In.	Elongation, %.	Reduction of of Area, %.	Izod Impact, Ft.-Lb.
Longitudinal .	24·0	36·0	31	58	55
Transverse ...	25·0	32·0	16	29	16

The chips come off shorter, and there is less tendency to tear and drag, or for the chips to build up on the edge of the cutting tool. Screw threads, in particular, are more accurately and quickly cut in this material.

This property of free cutting may be induced, broadly speaking, in two ways. One of the most usual ways is by

using a steel relatively high in sulphur, and thus containing a large amount of manganese sulphide. This, in the form of long threads, produces a striated structure both of itself and due to banding of the ferrite and pearlite. Such steels give a characteristic "rhubarb" fracture, once considered essential in a good casehardening steel.

These steels are definitely inferior in quality, and unsuitable for all but relatively unimportant grades of casehardened work, primarily because manganese sulphide or slag cannot be carburised and hardened, and the final case, therefore, is full of these hair lines of soft and brittle threads of unchanged sulphide.

A very high impact value *when tested at right-angles to the slag streaks* is characteristic of this grade of steel, but an impact test parallel to the direction of rolling reveals the non-uniformity and extreme weakness typical of the material. Table I. shows a set of tests on this class of steel, and Figs. 1 and 2 typical structures.

A rather more modern type of free-cutting casehardening steel is the carbon manganese type, where the banded structure is due solely to segregated ferrite and pearlite induced by particular treatment of a plain carbon steel high in manganese. A typical microstructure of such a steel is shown in Fig. 3. With this type the ultimate result is better, and if a free-cutting steel is preferred it should be used, since it contains no more slag or no higher sulphur contents than the normal plain carbon steels. Where, however, there is no guarantee that the stresses will all be at right-angles to the direction of rolling, as in the case of gears, it is better to use a steel whose properties and structure are nearly similar in all directions.

Nickel Casehardening Steels.

The last ten years has seen a tremendous rise in popularity of the nickel casehardening steels, and quite rightly so. In comparison, the nickel steels are in many ways superior to the carbon steels. The increased consumption of this class of steel has led to marked economies in manufacture, with the result that straight nickel casehardening steels are now purchasable at a lower figure than obtained even five or six years ago. Each 1% of nickel adds approximately £2 5s. per ton to the price of the steel, presuming no wastage from cropping losses. Increased care in sorting and segregating nickel scrap—*i.e.*, turnings, billet and bar ends, and crop ends has resulted in the extra price being little higher than called for by the alloy content.

The most valuable of the nickel casehardening steels is that containing 0·12–0·16% carbon, and from 3·4 to 3·7% nickel. Unfortunately, due to premature standardisation and insufficient appreciation of the metallurgical characteristics of the nickel steels, the 3% nickel casehardening steel obtained a firm hold in the engineering trade before the superiority of the steel bearing an extra 0·5% of nickel was realised. So that to-day the larger amount of the nickel steels used for casehardening contain from 2·75 to 3·1%.

The big advantage of the steel with 0·12% minimum carbon and 3·4% minimum nickel is that this steel will have the core *fully refined and hardened* every time with a single quench at 780° C. With the lower nickel content unless the carbon is high (say, 0·17%), and above the maximum called for by British Standard specifications the core will not refine and harden with a single quench at 760/780° C. after carburising with normal soaking times. Thus, in commercial practice parts made from steel to conform to B.S.S. 5005/13 or Airboard 3 S 15, will be found in the majority of cases to have at least a partially unrefined and hardened core if subjected to a normal heat-treatment calling for a single quench only after carburising. It is hoped, therefore, that this difference between the 3 and 3½% nickel steels—pointed out previously by the author many years ago, and now recognised by most steel-makers—will lead shortly to a revision in our standards, and thus greater uniformity in practice.

Differences between Carbon and Nickel Steels.

One of the great advantages of the nickel casehardening steels is that it is more foolproof. Much greater latitude is permissible in carburising and heat-treatment. This is largely due to the less rate at which grain growth takes place when the steel is heated above or maintained at a temperature above the change-point. The greater toughness of the case and the property of resisting cracking and peeling are of material advantage in service. The high core strength after correct heat-treatment—namely, 45 to 55 tons per square inch, enables higher surface loads (with the same depth of case) to be carried than is possible with low carbon steel without danger of the case collapsing.

The rate of penetration of carbon under equal temperature conditions is, if anything, slightly lower than with the low carbon steel, but this difference is of no practical import. Slight differences in carburising temperature, density of carburising material, shape, weight, and distribution of carburising boxes, make much more difference to the depth of penetration in a given time than the difference in the rate of penetration between the carbon and nickel steels.

Similar remarks apply to the difference in hardness of the case with a carbon and a nickel steel. Nickel steels

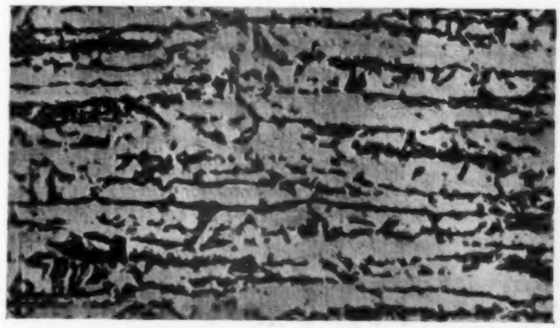


Fig. 3—Typical longitudinal section of free-cutting casehardening steel of the high manganese type. Magnification 100 diameters.

when casehardened are usually credited with having a lower surface hardness than carbon steels. This is to some extent true. The maximum surface hardness obtainable with normal carburising method with carbon steels is about C 68 (Scleroscope 91) on the Rockwell scale. This is with a first quality electric or acid steel. Indifferent quality steels either basic or acid may have a maximum of only C 62 or C 63 (Scleroscope 82 to 84); 3 or 3½% nickel steels have a maximum of C 66 (Scleroscope 88).

Errors or imperfections in either carburising, re-heating and quenching, and particularly in subsequent grinding, can and do account for far greater differences in hardness than that due solely to the nickel content; but there is no reason why an unground casehardened part of practically any section or configuration should fall below Rockwell C 63 (Scleroscope 85) in a nickel steel, or below C 60 or C 61 (Scleroscope 80 or 81) in the ground condition.

Another desirable characteristic, already briefly touched upon, is the possibility with a nickel steel of using a single quench (and that in oil) after carburising, which effectively refines and hardens case and core. This is of great value where distortion must be kept to the minimum. The greatest drawback to the process of casehardening is the distortion which parts so treated undergo. This distortion is due to the maintenance of the parts at a high temperature for a long time during carburising, and to the subsequent drastic quenchings. Obviously, if the number of quenchings can be reduced from two to one and that quenching takes place in oil instead of water, the distortion is considerably minimised. This single quench is particularly valuable where subsequent grinding to correct distortion is impossible or impracticable. With certain types of gears, such as spiral bevel gears (generally used nowadays as the final drive for motor-cars), grinding the teeth is impossible, and casehardened alloy steels are the only materials capable of standing the stresses with the sizes permissible and it is essential that only a single quench be used to minimise distortion and thus quietness in operation.

The great danger to be constantly watched, if it is desired to take advantage of the single-quench method, is the formation of excess or free cementite during the carburising operation. Provided case depths of not more than about 0·040 in. are required, and the carburising temperature is not above 880° C., and a suitable carburising compound is used, this is fairly easy. It is, however, imperfectly appreciated that a single quench at 780° C. in a 3 or 3½% nickel steel will not break up a cementite network if this should be present, due to non-observance of one or other of the conditions given above. Cementite network persisting in the corners on a casehardened article is a most fruitful cause of troubles in service. Such corners are extremely brittle and readily spall, particularly under shock loads. For this reason it is highly desirable to use for test-bars in casehardened work those of square section. For obvious reasons, excess cementite makes its appearance on corners more readily, and if round test-bars are used these may show no trace of "freckled edge," whereas the actual corners of the parts may do so. With round test-bars one may, therefore, be easily and seriously deceived, with disastrous results in service. If "freckled edge" does make its appearance on work where a single quench only is desirable, there is, of course, no option but to give a high-temperature treatment (normalising or oil quenching from 900° C.) to remove it, and the extra distortion has to be borne. The probability of obtaining excess cementite, where case depths of 0·060 in. or above are required, is much more likely, and if a single quench is still required, very low carburising temperatures and careful selection of carburising compound is necessary.

Where double quenching is practicable—*i.e.*, where grinding takes place afterwards, it is often advisable to aim for a certain excess of carbon—that is, a case where outer layers contain 1·2 to 1·4% carbon on account of the greater surface hardness such cases possess after hardening. Provided the network is thoroughly broken up by a high temperature quench at, say, 920° C., the slight extra brittleness consequent upon the higher carbon case is often more than compensated for by the extra hardness and greater resistance to wear.

When dealing with cases of this type, however, it cannot be too strongly urged that square test-bars of similar material should accompany the work through every operation in hardening, and finally broken to check the depth and character of the case in the actual article. Care is, of course, needed to allow for the different mass of the test-bar and the work, but experienced discretionary treatment should ensure no errors on this account.

In considering the selection of suitable steel for any casehardened part, it should also be borne in mind that the superior core strength of the alloy steels is advantageous in respects other than that of affording adequate support to the core.

It is often preferable to caseharden only those portions which are subject to direct abrasive wear. For instance the cams only in a camshaft, or the worm portion only in a worm-shaft. Reliance can then be placed on the superior strength of the alloy steel to carry the torsional or bending loads in the uncasehardened condition. This often results in economies in manufacture. For instance, a splined end, where great accuracy of splines is required. Here, if the splined end is casehardened, grinding is necessary to rectify distortion. If, however, the splined end is left uncarburised (by copper plating or other means) and subject to the same heat-treatment as the other portions of the part, a core strength of 45 to 70 tons (dependent on the class of alloy steel and the treatment) can be obtained in the splined end and the splines milled accurately after treatment, avoiding the grinding operation.

In camshafts, carburising the cams only results in a shaft much easier to straighten after hardening, since the hard case is present only where actually needed—*i.e.*, on cams and journals. It is usually preferable, if a sufficiently strong alloy steel can be used, to leave non-wearing parts uncarburised, to allow machining after hardening.

(*To be continued.*)

A.S.T.M. Form New Committee to Study Spectrographic Analysis.

The rapid increase in the use of the spectrograph and the necessity of correlating data has caused the American Society of Testing Materials to form a new standing committee. The importance of the work and the rôle of the spectrograph in industry was outlined by H. V. Churchill, of the Aluminium Co., of America, who has been appointed chairman of the new committee. Fundamentally, it has two major functions: as a qualitative tool and as a quantitative tool.

As a qualitative tool, the spectrograph is of primary value as an accessory instrument to be used as an adjunct to other methods and modes of examination. It has a definitely recognised field in analytical chemistry. It is the simplest, most direct, and most nearly infallible method of detecting the presence or absence of most elements. It serves here in two main ways. It affords a simple, accurate, and ready method for preliminary examination of samples prior to actual analysis. It also is a simple and satisfactory method of examination to be used subsequent to chemical analysis to ascertain whether or not some element has been overlooked. The second qualitative use to which the analytical chemist satisfactorily may put the spectrograph is in connection with the development of testing of methods. In this case, the spectrograph is a ready means of determining the presence or absence of many elements in particular filtrates or precipitates.

The above uses of the spectrograph by the analytical chemist naturally involve the development of a specific technique. By simple examination of the spectrograms, one is able to make rough quantitative deductions. The experienced spectrographer is enabled with unexpected accuracy to rank the elements shown on the spectrographic plate in order of their relative abundance. This type of work is of extreme significance in analytical chemistry.

The metallurgist or the metallographer may find the spectrograph of value to him in his investigations. Most chemical analyses are of an average type. By this is meant that chemical analyses from the size of the sample necessarily involved include rather large amounts of materials. In the study of the constituents of alloys or compositions at particular areas the local analyses made possible by the spectrograph present great possibilities.

In this modern day, when the possible tremendous influence of small amounts of constituents or elements has attained new conscious significance, the rôle of the spectrograph becomes increasingly important.

In the routine inspection or sorting of metals, the spectroscope and the spectrograph present many new possibilities. The comparison of the spectra of unknown materials with the spectra of known or master samples presents possibilities for time and effort economy. The student of corrosion will find the spectrograph an interesting and valuable tool in the study of corrosion products and of corrosion phenomena in general.

From a quantitative standpoint, the spectrograph presents many possibilities, most of which are not realised in actual practice except in a limited and localised manner. Fundamentally, quantitative spectrography depends upon the relative intensity of the spectrum lines on a photographic plate. It becomes apparent at once that the success of quantitative methods finally depends upon the accurate measurement of this intensity. Therefore, means must be devised or utilised for measuring the relative blackness of certain photographic plate areas.

Methods for the measurement of line density are essentially optical in character. There are two methods in vogue in quantitative spectrography at this time. First, there are those methods which depend upon simple visual comparisons. Second, there are the methods which make comparisons by means of specialised photometric instruments.

Heat-Treating and Forging Some Light Alloys

The need of care and control in working Duralumin, "Y" alloy, and the R.R. alloys is emphasised. A type of test is discussed, and an etching solution is suggested for showing the presence of cracks or defects in forgings.

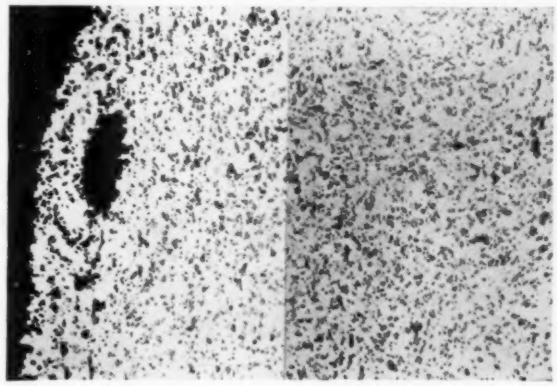
THE heat-treatment of the aluminium alloys is probably more advanced than that of any other type of non-ferrous material. This position is largely due to the rapid manner in which the results of much recent research and experimental work have been assimilated by industry. The development of these heat-treatable alloys is undoubtedly the most notable example of metallurgical evolution in recent years, and many workers in this field are to be congratulated on the remarkable results achieved.

Probably the more important of these alloys are Duralumin "Y" alloy and the series of R.R. alloys, all of which were recently discussed by Mr. W. C. Devereux before the Sheffield Society of Engineers and Metallurgists. They are obtainable in the extruded, forged, and stamped condition, or as sheet tube and other semi-finished forms, and their chemical analyses are given in Table I. Although their development is comparatively recent, they have in many instances replaced steel forgings and stampings, the advent of the R.R. 56 alloy making this quite practicable.[1]

More care and control, particularly at temperatures of working, is necessary in the production of good aluminium stampings and for forging than is the case with steel, and

Fig. 1.—Rod blistered in heat-treatment operation.

although Mr. Devereux state that he used electric furnaces, gas furnaces may be useα, but they must be designed to work for these operations within a range of ± 7 to 10°, and there should be perfect unitormity throughout the furnace. For heat-treating operations the furnace should be definitely controlled to within ± 3°, and, if using a gas furnace, the gas flame should not be allowed to come into contact with the work, or trouble is liable to arise. After each heat-treatment, under such conditions, the part will be found to be blistered on the surface as with the connecting rod in Fig. 1. This blistering is usually associated with overheating, but in this case it is not due to this cause, as an overheated connecting rod would break off short if twisted. The rod shown, however, has twisted quite well, and a microphotograph shows the structure of the material in the particular rod in question to be perfectly sound. The blistering is no doubt due to the absorption of hydrogen and products of combustion in the surface of the material in places, and is shown when subjected to the solution temperature of heat-treatment causing a hole immediately under the skin of the rod. The micrograph, Fig. 2, shows on the left a section cut through one of these blisters, while the centre of the stamping is shown



SECTION THROUGH BLISTER. STRUCTURE AT CENTRE.

Fig. 2.—Microstructure of blistered rod.

on the right. This blistering is distinct from that which would occur from overheating, which would result in the fusion of the eutectic of the material.

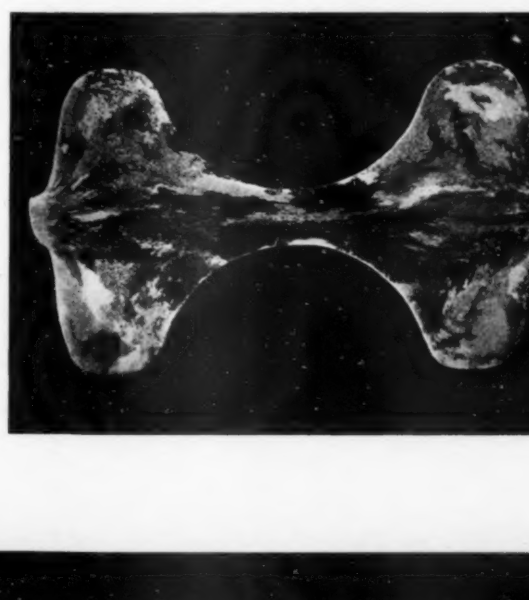
Better stampings will result from blanks or bars that have been entirely forged, said Mr. Devereux, but a cheaper method of manufacture is to work from extruded or rolled sections. Troubles, however, can arise from the use of

TABLE I.
PERCENTAGE COMPOSITION OF FORGING ALLOYS.
Remainder—Aluminium.

Alloy.	Copper.	Nickel.	Magnesium.	Titanium.	Iron.	Silicon.
R.R. 56	2·0	1·25	0·80	0·08	1·35	0·6
R.R. 59	2·2	1·35	1·5	0·08	1·35	0·8
Y alloy	4·0	2·0	1·5	—	Impurities	
				Manganese.		
DTD.18 C. .... (known as Duralumin)	4·0	—	0·55	0·5	"	

extruded or rolled bar unless precautions are taken during manufacture. During extrusion at certain temperatures and time, the plastic deformation of the material is such

Fig. 3.—Grain growth resulting from long soaking.



1 Devereux in paper before Manchester Metallurgical Soc., METALLURGIA, December. 1931.

that subsequent heating for a length of time will cause growth of the crystal. To avoid such defects in stamping from extruded bar, the length of soaking should be as short as possible. The effect of long soaking is shown in the section of a connecting rod Fig. 3. The phenomena of grain growth is apparent in all extruded aluminium alloy sections, whether Duralumin, Y alloy, or R.R. 56.

To prevent the formation of crystal growth the bars for dummying should be soaked just sufficient to heat them through. The extruded bars may be lightly forged before dummying at a temperature of between 250°–300° C., or when the stamping is almost down to size the final stamping blows carried out at this low temperature. It should be remembered, however, that forging aluminium alloys at a low temperature is very destructive on dies. The life of a die block using aluminium alloys is less than one-third of that working on a similar part in steel.

Special reference was made to a new type of test which is done on the Amsler repeat impact testing machine. In this test the specimen receives a blow in the tensile direction, and the energy of this blow can be varied by altering cams. The interesting point in the test on this machine is the demonstration of the marked difference in the results between varied materials due to the fact that the yield-point appears to be the determining factor in a test of this nature, keeping in mind that an impact test also quickly registers likely inequalities in the structure of the materials. This machine, of course, combines an impact with a fatigue effect. The higher the energy factor in this test the greater will be the difference between two materials having similar ultimate strengths but considerably different yield-points. This is demonstrated in the following figures, which are taken from the average of six tests:—With the energy of blow at 1·16 ft.-lb. R.R. 56, with its high elastic limit, registers 5,600 blows; "Y" alloy, 180; and Duralumin, 150. With the energy of blow reduced to 0·517 ft.-lb., R.R. 56 registered 101,000 blows; "Y" alloy, 50,000 blows; Duralumin, 37,600 blows. Reduced to 0·351 ft.-lb., R.R. 56 gave 276,300 blows; "Y" alloy, 117,600; Duralumin, 85,000. Again reduced to 0·156 ft.-lb., R.R. 56 was unbroken after 3,000,000 blows; "Y" alloy broke at 353,300 blows; Duralumin at 246,000 blows. Mr. Devereux considers that, under general design conditions, the Amsler universal impact test more nearly approaches the working conditions of most parts in service than any other test, keeping in mind the fact that in the Wohler reverse bending fatigue type test the test is safeguarded against the smallest vibration, whilst, on the other hand, the Arnold type test gives a few reversals, each reversal being of such magnitude as to pass the yield-point, a condition seldom met with in practice.

The mechanism of age-hardening by heat-treatment was discussed, the principal theory of the mechanism being the precipitation theory. This theory defines age-hardening as being due to the precipitation of the dissolved material in the form of sub-microscopic particles from a supersaturated solid solution obtained by quenching. In the alloys under discussion the soluble constituents in the case of Duralumin are copper aluminides and magnesium silicide. It is stated that the copper aluminium compound $Cu\ Al_2$ does not exist in "Y" alloy, hardening occurring and ageing being due to the precipitation of magnesium silicide, and the constituent known as T, since the copper associates with the nickel to form a ternary inter-metallic compound containing both $Cu\ Al_2$, and $NiAl_3$, known as T. Besides the precipitation of magnesium silicide there is present in "Y" alloy a little $NiAl_3$ and a considerable amount of T constituents. Superior strengths of "Y" alloy at high temperatures is accounted for probably by the absence of $Cu\ Al_2$. In the case of the R.R. 56 material the hardening constituents include magnesium silicide, $Ni\ Al_3$, undoubtedly a little $Cu\ Al_2$, and some of the aluminium copper and nickel complex. There is purposely added titanium and iron, in the case of the titanium being introduced for the purpose of grain refinement leading to improved mechanical properties and tending to prevent also the growth of large columnar crystals. The inclusion of the iron forms a compound $Fe\ Al_3$, to act as an inhibiter to prevent ageing at room temperatures, this being a most useful property of the R.R. 56 material, particularly with sheet, which subsequently requires cold work, which means that after the high-temperature solution treatment the material can be cold-worked and bent with ease; precipitation—that is, low-temperature treatment—can then be conveniently carried out on the finished part, obtaining the highest properties without fear of distortion. The actual temperature of heat-treatment for the forging alloys mentioned are shown in Table II. It is necessary in the R.R. alloys to use an elevated temperature to cause precipitation of the solid solution, whereas the "Y" alloy and Duralumin age naturally, the period taking about five days.

TABLE II.
HEAT-TREATMENT OF FORGING ALLOYS.

Alloy.	Solution Treatment.			Precipitation Treatment.		
	Temperature.	Time.	Quench.	Temperature.	Time.	Quench.
R.R. 56	530° C.	2 hours	Cold Water	170° C.	20 hours	Cold Water
R.R. 59	530° C	2 hours	Cold Water	170° C	20 hours	Cold Water
Y alloy	520° C.	2 hours	Boiling Water	Natural	ageing (ab	out 5 days)
DTD.18.C. ...... (known as Duralumin)	490° C.	Sufficient for penetration of heat.	Water	"	"	"

The effects of over-heating are not easily detected by the physical properties as laid down by the various standard specifications, the figures of such specifications not being sufficiently high. The most satisfactory way, of course, of detecting this overheating is by microscopical examination.

To show any defects or cracks, forgings are etched to get a white finish. Care, however, is required in this operation, particularly with forgings that will be used in the unmachined condition, owing to the effect of the minute pitting on the fatigue value of the material. Caustic-soda etch is used by most people, but its attack is bad and erratic, and a better etch is obtained by dipping the forgings in one part of hydrofluoric to four parts of 10% sulphuric acid for 6 to 8 mins.; dip in water to wash off, and then cleaning the deposit by dipping in a nitric acid bath, again washing in water. Some tests have been carried out to show the effect of the various etching mediums on the fatigue value, the results of which are given in Table III.

TABLE III.
REPORT ON THE EFFECT OF CAUSTIC ETCH ON THE FATIGUE LIMIT OF FORGED AND HEAT-TREATED R.R. 56.
H.D.A. parallel test-pieces 13·5 m/m. dia. Tests carried out at 9·0, 9·70, and 10·0 tons per sq. in.

	Normal Etch.	Load.	Over-Etch.
Standard etching solution	20,000,000	9·0	9,076,800
Caustic etching soluton...............	20,000,000	9·0	8,012,000
Standard etching solution	4,853,600	9·7	1,399,800
		9·7	1,475,800
Caustic etching solution..............	3,114,800	9·7	1,618,800
		9·7	1,323,200
Standard etching solution	3,861,600	10·0	1,019,000
Caustic etching solution..............	2,101,400	10·0	986,400

Caustic etching solution, 10%. Normal etch, 8–10 mins. Over-etch, 30–40 mins.
Average tensile results on bars used:—

0·1% proof stress	22·2 tons per sq in.
Maximum stress...............	28·7 " "
Elongation....................	12·4% on 2 in. G.L.

It is of interest to learn that heavy stampings are now being made, the largest up-to-date weighing 450 lb., while forgings have been made up to 15 cwt.

Welding Machine Manufacture.

The growth of the welding-machine department of New Process Co., Ltd., has led to the formation of an independent concern for the exclusive manufacture of N.P.C. welding machines, trading under the name of The New Process Welders, Scott's Road, Southall, Middlesex; but this does not involve any change of management, manufacture, or policy.

Coke in Metallurgical Melting and Heating Practice

By R. J. Sarjant, M.Sc., A.R.C.S., D.I.C.

Under suitable conditions of combustion the hard metallurgical cokes have a wide range of uses. The author discusses some desirable features of coke which are important factors governing its use.

THE production of the coke used, amongst other purposes, for the melting and heating of metals has evolved through two courses, the one originating essentially from its production as a by-product in the manufacture of illuminating gas in the latter years of the eighteenth century, and the other, of great antiquity, from the practice of the beehive coke oven for the supply of hard coke for the smelting of iron in the blast-furnace. In the case of the former practice the industry originally produced a readily ignitable and soft coke in cast-iron retorts, which permitted only relatively low temperatures of carbonisation. The modern development of the gas industry and the wider market for town's gas has resulted in the utilisation of higher temperatures in the coking process. These changes and the evolution of the continuous vertical retort with steaming of the charge, introduced to increase the make of gas, have resulted in a gradual change of the character of the coke. The cokes made in modern high-temperature gas works are intermediate in general characters, and notably in combustibility, between the softer cokes of the past and the hard burnt cokes used for iron smelting. The future requirements of the domestic market for freer burning coke will probably bring about retracement of this course of evolution, and there will accordingly become available increasing quantities of softer or more freely burning cokes. The improvement of the practice of the patent oven plants making metallurgical coke, together with the economies resulting from the recovery of by-products and surplus gas, has resulted in the almost entire disappearance of the beehive oven, except for the purpose of coke burning for the melting of special steels by the crucible process. By far the greatest proportion of the oven coke produced is utilised in the production of pig iron in the blast-furnace. This use is attended with special problems associated almost exclusively with the iron and steel industry, and considerable attention is being directed to the subject by the various research organisations associated with the industry. Another important metallurgical use is the melting of iron in the cupola, but actually in point of tonnage there is only about 5% of the total output utilised in this manner. Approximately one-third of the output is supplied either for export or domestic use.

In the case of gas coke an equivalent proportion to the oven coke used for blast-furnaces—namely, about two-thirds of the total output—is put to domestic use. Statistics as to the proportion used for industrial furnace heating are not available, but a wide diversity of use is practised both for closed furnace chambers utilising grates, and on blast-driven hearths.

General Characters of Metallurgical Cokes.

The properties desired in coke for metal heating are essentially distinct from those required for good domestic coke. Two types are recognisable, one the hard metallurgical coke required for blast-furnace and cupola purposes and the other more readily combustible, for direct furnace heating either on a thin fuel bed or for gas-producer practice. Under suitable conditions of combustion the hard metallurgical cokes may be used for the wider range of uses, though these latter are less important from the standpoint of the quantity consumed.

Chemical Factors.

The heating value of a coke is indicated sufficiently accurately for general purposes by the carbon content of the fuel. This is readily deduced by deducting the sum of the contents of ash, volatile matter, and sulphur in the case of the dry coke. The moisture content of a coke is not an indication of quality in the same sense as it is in the case of coal, because the moisture arises from the water used in quenching, or wetting from exposure to the atmosphere in rainy weather. Moisture is, however, a deleterious constituent because it carries off sensible and latent heat in the products of combustion. In the blast-furnace the loss of heat equivalent to 1% of moisture is represented by 0·1% of the coke charged in the case of an exit gas temperature of 450° C. In the same use not only is the ash a diluent, but its composition has an effect on the basicity of the slag. Each 1% of ash increases the coke consumption per ton of pig iron by at least ½ cwt. when the standard coke consumption is 20 cwt. per ton. In general, sulphur falls into the same class of diluent, except in the case of the production of hæmatite iron, or the heating of special metals, in which any sulphur beyond 1·5% is regarded as undesirable. In the case of cupola melting, it is important that the sulphur should be at a minimum. Sulphur may be present as ferrous sulphide, adsorbed free sulphur, as the element in solid solution in carbon, as metallic sulphates, possibly as calcium and magnesium sulphides, but the majority is present as organic sulphur, and this is the most deleterious form. Phosphorus is only of significance in the production of iron for the melting of acid steel. Arsenic is also of secondary importance in metal heating and melting.

Physical Properties of Coke.

By far the most important characters of coke are revealed in its physical properties, since the manner of its combustion is governed by such properties. A considerable amount of research has been carried out in attempts to define the relation between the determinate physical characters and the behaviour of coke during combustion. In evaluating the latter two characters have been extensively investigated: (i) the reactivity to carbon dioxide, and (ii) the combustibility in air or oxygen. Both take part in governing the combustion process. In the case of the blast-furnace the products of direct reaction with oxygen in the zone immediately above the tuyères are brought into contact with coke at the upper layers of the furnace. Accordingly the reactivity of coke with carbon dioxide, or the rate of solution of the coke in carbon dioxide becomes a governing factor in its suitability. Sir Lowthian Bell[1] first drew attention to the significance of the reactivity between carbon and carbon dioxide, and in 1884 published figures showing the amount of reduction of carbon dioxide which was occasioned by different cokes when heated under similar conditions in a stream of the gas. Investigations have not as yet provided any definite answer as to whether

1 Bell, "Principles of Manufacture of Iron and Steel" (Routledge, 1884).

high or low reactivity is the more desirable for blast-furnace purposes. The examination of a coke as charged and after reaching the tuyères has shown that coke from the tuyère level was in every respect more active than that supplied to the furnace. This increase of activity was found to be due to increase of reducible iron arising from conversion to that state in the course of descent through the furnace. The ash composition is probably a governing factor in determining the different amounts of reducible iron. This may be the reason why cokes are found to be capable of classification, on the basis of the reactivity values, according to the districts from which the parent coals are obtained. Thus, the least reactive cokes are made in South Wales and Durham. The Yorkshire cokes are reactive. There are distinct differences in structure, the Yorkshire cokes being prismatic, having at the bench a relatively high content of moisture, which is generally associated with physical weakness. The Derbyshire cokes have these properties more marked, and are furthermore fissured. The South Wales coke is made from coal containing about 90% carbon in the ash-free dry coal, and 20% of volatile matter. The coke is dense, of fine porosity, and stout cell wall. The Durham coke, slightly less reactive, is made from coal containing 86–89% carbon and 25–30% volatile matter. It is blocky, of more silvery grey lustre, and very hard. The structure is affected by the type of oven, and varies in different parts of the oven.

TABLE I.
ANALYSIS OF COKES USED.

Coke No.	Description.	Moisture %.	Ash, %.	S, %.	Density.		Porosity, %.
					Appt.	True.	
1	Horizontal retort	2·48	12·8	1·72	0·84	1·82	54·1
2	Beehive (S. Yorks.)	0·82	9·7	1·56	0·83	1·91	56·5
3	Beehive (Lancs.)	1·32	10·1	0·66	0·95	1·84	48·3
4	By-product (S. Yorks.)	0·60	13·0	1·51	1·08	1·93	44·0

Generally, the less reactive cokes are favoured for blast-furnace use, and certainly in cupola practice low reactivity to carbon dioxide is essential. In the latter case it is desirable that the gases passing from the throat should have a minimum content of carbon monoxide in order to lessen the loss of potential heat due to unburnt combustible in the throat gases. Also the less reactive cokes in general give a higher temperature in the melting zone of the cupola. This is to be expected, since the overall development of heat of combustion in a given volume of melting zone must be higher with the increased ratio of CO_2/CO, which the unreactive cokes give.

Combustibility.

Combustibility is usually defined as the speed at which the carbon unites with oxygen, and is determined by investigations in fuel beds of the initial rate of decrease of oxygen in the gases. Actually, the rate of combustion has no influence on the final products of combustion. The relative mean combustibility of various cokes is different in different parts of the fuel bed. Sherman and Blizard[2] have shown that the mean combustibilities of a number of different types of coke when burned at the rate of 25 lb. per sq. ft. per hour, was practically the same in each case. Nevertheless, there are marked differences of behaviour in this respect of cokes of various types both in the blast-furnace and in the cupola. It is to be expected, as regards the reaction $C + O_2 = 2CO$, in which the natural rate of reaction is exceedingly fast, that the manner of access of the oxygen to the coke should govern the speed of combustion. That is to say, that combustibility must be governed primarily by the size of the coke—an overruling circumstance, since it constitutes the major dimensions governing the access of the oxygen to the carbon. The porosity, and particularly the nature of the porosity, must be the next important factor. Indeed, the elegant method of Rose,[3] whereby a section of the coke may be examined readily, combined with microscopical examination of the nature of the finer porosity, is a more fertile means of assessing its significance rather than any specific value of the volume of the pores. The method utilises a mixture of plaster of Paris and 2% of magnesia, in which the coke is embedded. When set, a section may be prepared with a carborundum cutting-wheel and subsequent grinding on a glass plate till smooth. Finally, the nature of the cell wall is significant. In the beehive cokes the low reactivity has been ascribed to the "methane carbon" deposited in the cell walls during coking. Rumdohr,[4] in 1928, found from examination of thin slices that the coke carbon may exist in a more or less graphitic form. Koppers and Jenkner[5] have used a measure of the electrical conductivity as a means of determining graphitic carbon. The content of graphitic carbon was found to be influenced by coking property. The degree of graphitisation which tended to reduce combustibility is first reached at 800° C., when the graphite particles begin to attain a size which makes them less susceptible to reaction.

Some thirteen years ago the author instituted in the steelworks with which he is associated the shatter test as the most satisfactory means of evaluating the physical properties of coke. This test has now been standardised by the Coal and Coke Committee of the American Society of Testing Materials, and by the Coke Research Committees of the Iron and Steel Industry. It consists in dropping 50 lb. of coke, in size over 2 in. mesh from a box with bottom swinging doors, on to a cast-iron or steel plate through a distance of 6 ft. Four drops are made, and the coke is then screened through 2 in., 1½ in., 1 in., and ½ in. screens. Extended use of the test over some thousands of samples of coke has, from the author's experience, indicated that the cokes most serviceable for cupola operation give a good shatter index, that the proportion through the 2-in sieve is a sufficient practical indication in routine testing of the quality of the coke, though the 1½-in. index is equally satisfactory, and may be preferable in some cases. In the case also of crucible cokes, and furnace coke used for general heating purposes, thus mould-drying stoves, for example, the test is a valuable index of quality, for not only does it indicate the proportion of small coke which may result from repeated handling, but it indicates a coke which will give a high temperature in the fuel bed, under comparable conditions of size and draught. In the case of cupola practice, also under standard conditions of rate of driving, class of charge and general conditions of cupola operation, the coke giving the best shatter index will give the hottest metal. Typical 1½ in. shatter indices, according to the tests of the Midland Coke Research Committee are: South Wales, 97; Durham 91; Yorkshire, 81; Derbyshire, 70. The abradability is best indicated by the ½-in. index.

Metallurgical Uses: Specifications.

In the foregoing discussion the desirable features of a coke for use in the blast-furnace have been indicated. An important factor governing this use is the geographical location of the coke ovens and the blast-furnaces. The stress of economic pressure in the iron and steel industry of this country is demanding unification of the coke ovens, blast-furnaces, and steel works, whereby economy of fuel and shop operation is favoured by the utilisation of surplus gas. Accordingly, coke quality is largely influenced by the major factors of local conditions. The ideal of blending in the most satisfactory manner may not always be practicable, and the utility of a specification is excluded in the ordinary sense. However, in the case of coke for foundry purposes, cupola melting and general practice in furnace heating specifications have a definite value. The following may be regarded as a suitable specification for cupola practice :—

2 *Amer. Inst. Min. and Met., Eng.*, Feb., 1923, and U.S.A. Bur. of Mines.

3 H. J. Rose, *Ind. and Eng. Chem.*, Sept., 1925, p. 895.
4 See Ref. 5.
5 *Arch. Eisenhuttenw.*, 1932, May 5, 543-547.

Moisture.—To be a minimum.

Ash.—8%.

Sulphur.—Grade I, 0·8; Grade II, 1·0.

Hardness.—1½ in. shatter index as high as practicable and preferably over 90. Alternatively 2-in. index.

Size.—Less than 6% through 2 in.

In these days of the use of desulphurising processes the need for the low sulphur content on the grounds of quality of the product alone is of less importance, and the dominant characters to be demanded are purity as regards ash and good shatter index. Exclusive of desulphurising processes, sulphur pick-up during melting is less pronounced with a hot melting coke, and a higher sulphur content is tolerable with a coke of high-shatter index.

Crucible Melting.

The properties sought in steel-melting cokes for use in the older crucible process, which is still favoured for certain grades of high-class tool steels, are only encountered to the maximum degree in beehive coke. A particular combination of properties is demanded by the size of the furnace chamber, and the nature of the draught provided in the "pot hole." The chief requirement is that the coke should burn at an economical rate to suit these conditions, and produce a maximum development of heat in the fuel bed. Accordingly, the coke must be of low reactivity, and give a high CO_2/CO ratio in the gases issuing from the fuel bed. A particular long slender shape is required to facilitate packing into the space between the crucible and the ganister lining of the furnace. Beehive coke alone gives this desired shape, since there is an absence of cross fractures which are characteristic of by-product oven cokes which produce blocky shapes. Most significant of all characters is the possession of a sonorous ring, which is an index of a uniform and sound structure.

TABLE II.

MELTING TESTS—AVERAGE RESULTS.

Coke.	Weight of Coke Used.	Weight of Metal Melted.	Time.	Fuel Ratio, Coke/Metal.	Fuel Consumption per Hour.	Metal Melted, per Hour.
	Lb.	Lb.	Mns.		Lb.	Lb.
1	93	105	135	0·88	41	40·7
2	75	105	110	0·71	41	57·2
3	86	105	90	0·82	57	70·0

TABLE III.

COMPARATIVE CRUCIBLE STEEL MELTING TESTS FOR BEEHIVE AND BY-PRODUCT COKES.

Coke.	Weight of Coke Used.	Weight of Metal Melted.	Time.	Fuel Ratio, Coke/Metal.	Fuel Consumption per Hour.	Metal Melted per Hour.
	Lb.	Lb.	Mins.		Lb.	Lb.
2	315	262	255	1·20	74	61·8
4	286	262	400	1·09	43	39·3

The above is a record of a series of melting tests on various types of cokes to test their relative values. In all tests the size was kept uniform. From the results indicated in Table II., it is apparent that although the fuel consumption was high more rapid melting could be obtained by the denser Lancashire coke No. 3. Accordingly, a dense by-product coke (No. 4) from the same type of coal was tested against the beehive coke commonly used (No. 2). Table III. indicates the results obtained. Although the requisite temperature could be obtained with the by-product coke and the consumption per pound of metal melted was satisfactory, the rate of melting was found to be too slow for practical requirements.

Clinker formation is a critical index of an unsuitable coke. It has been suggested that the more regular structure of the beehive coke favours a more uniform burning throughout the mass, and therefore enables the coke to be used without excessive clinker formation. A circumstance of greater significance is the refractoriness of the ash. Certainly in crucible melting and in normal heating-furnace operation high refractoriness of the ash is to be favoured. A refractoriness of 1,350° C. for the lower limit of the fusion range in a reducing atmosphere is a reasonable demarcation between a good and an inferior coke in this respect.

General Heating.

A wide range of quality is practicable for general heating purposes. The character of the coke admissible in any given utility is mainly governed by the draught available. The clinkering properties of the ash are important, the cleaner the coke and the more refractory the ash, the more satisfactory is the fuel from the standpoint of operation. Provided adequate control and distribution of draught is available the question of suitability largely devolves upon the economic question. Cokes having a high proportion of volatile matter and high reactivity are associated with diminished radiation efficiency. The high radiating efficiency of a coke fire, associated with the interesting circumstance that carbon has the highest emissivity of any known substance, gives to the use of coke a special value in many metallurgical operations, thus the blacksmith's forge fire, ladle heating, crucible melting, drying, etc. Also the absence of undue proportions of moisture in the products of combustion makes it an advantageous fuel for metal heating where the proportion of scale is to be minimised. Admixture of coke with coal is an expedient to reduce smoke production in lighting up furnaces from the cold.

Machine Shop Engineering, Vol. I.

THIS book contains six lectures delivered this year as part of the course in tool engineering at the College of Engineering of the University of Michigan. It is the first of a series of small books which we understand are to be published dealing with machine-shop processes, and it is primarily intended for foremen, draughtsmen, tool-and-die makers, and machinists. The subjects upon which the lectures are based include—the engineer in modern production; the design, fabrication, and use of milling cutters; twist drills and broaches; milling and drilling processes; and modern large-scale forging.

In a foreword by the editor, Alexander P. Gwiazdowski, who is assistant professor of shop practice at the University of Michigan, it is stated that both employer and employee must realise how much economic success will depend upon the increasing intelligence of the mass of the workers in addition to the relatively few who supervise mass effort. The workers must be transformed gradually into administrative and technical superintellectuals and their mental energies will be shown in the creative power of the nation.

The object of these volumes can be appreciated in view of the general tendency towards mass production, which converts the worker into a machine unless he possesses more than ordinary acumen and realises the need for keeping himself acquainted with modern developments in his field of activity. The method of conveying the information given in these lectures is distinct from the method of approach given in text-books, but this is rather an advantage that should add to their usefulness. The text matter is presented in an admirable form, and the salient points which arise are readily grasped. There can be no doubt that a series of volumes prepared on similar lines to this volume will be very valuable to those engaged in the machine shop, but we think many of the illustrations are of little value. We suggest that a larger margin be left about the text, as it seems to us desirable that room should be left for occasional notes being added by the owner of the volume.

By A. P. Gwiazdowski; published by Machine Shop Engineering, 1503, Shadford Road, Ann Arbor, Michigan, U.S.A. Price, single copy, 75 cents; two copies, $1·00 post free. Manufacturers may obtain quantities of ten copies and over at 35 cents per copy.

Reviews of Current Literature.

Protective Films on Metals.

To calculate the enormous loss sustained year by year as a result of the corrosion of metals would be impossible there can be no doubt, however, that it would represent an impressive amount. In view of the importance given to economic considerations, and the modern progress in metallurgy, it is not surprising that many investigators have given considerable attention to the problems associated with this continual loss. Certainly a remarkable amount of successful research work on the subject has been carried out during recent years, not only with the object of elucidating the factors that determine the rate and character of corrosion in any particular case, but also to seek fundamental causes and apply remedies. So many factors exert an influence on the metal, however, that, with increasing knowledge, the problems associated with corrosion become more complex.

In a measure this is due to the rapid increase in the number of metals and alloys now finding industrial applications in which they are exposed to the atmosphere and various other corrosive media; but the complexity is also increased by the difficulty experienced in assimilating the results of research so that they can be applied with every confidence in reducing the huge loss corrosion, in its many forms, entails. It is primarily with the object of overcoming this latter difficulty that this valuable work by Dr. Hedges has been prepared and published.

The importance of allaying corrosion has long been appreciated, and many methods, founded on scientific principles, are familiar to the engineer, metallurgist, chemist, and others who have experience of the behaviour of metal structures. One method is to treat the surface of the metal, covering it with a material that is resistant to corrosion. This form of protecting film is provided by means of a layer of another, less corrodible, metal; by a film of paint, varnish, bituminous material; or by means of oil or grease. Another method is to effect protection by means of a film of oxide. Much research work during recent years has been conducted on the properties and isolation of thin films which form spontaneously on metals under certain conditions and protect them from further attack. Whether these protective films are acquired spontaneously or by artificial means, however, they depend for their success on uniformity and perfect continuity over the entire surface.

The results of the most important researches on protective films are incorporated in this book. In doing this the author has had no light task, but he is himself an authority on the subject, and this fact has enabled him to assemble the most salient factors and discuss them with a knowledge only experience over a wide field can give. The comprehensiveness of the field covered can be judged from a brief reference to the subject matter considered, which includes the mechanism of corrosion; the protective effect of oxygen on metals; protective films formed during atmospheric corrosion; protective films formed in liquid media; anodic films; practical application of oxide and other films; coating by hot dipping; electroplating; sprayed metal films; cementation; various protective metallic films; paints, lacquers, enamels, and other artificially applied films.

Dr. Hedges has the happy knack of lucidity in discussion, with the result that this book is not only informative but the subject is presented in an interesting manner—a fact which adds to its value. It will undoubtedly appeal to all those interested in current research, but the survey will also be appreciated by the engineer who is more concerned with the application of the results of research.

This book is particularly welcome at a time when the subject of corrosion and the importance of protective films are receiving so much attention, and we have no hesitation in recommending it to all seriously concerned with the solution of problems involved. It forms the fifth of a series of monographs on applied chemistry under the editorship of Dr. E. Howard Tripp, and it is a worthy production.

By Ernest S. Bridges, M.Sc., Ph.D. (Manchester), D. Sc. (London), A.I.C. Published by Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price, 15s. net (postage 9d. extra).

Colorimetry.

RAPID advance is being made in the colorimetric branch of analytical chemistry. It is being used to give accurate quantitative determinations of the concentrations of two-coloured solutions of the same dyestuff by optical comparison, and is being developed into a widely applicable quantitative micro-method. The method is applicable to the determination of numerous substances which are capable of giving colour reactions, and its development is undoubtedly due to the rapidity, as well as accuracy, of the determination. Owing to the great sensitiveness of colour reactions minute quantities of material are sufficient for quantitative determinations. It is finding increasing usefulness in medico-chemical work; pharmacologists and pharmacists find it a useful method in the investigation of medicaments; the forensic chemist and food chemist apply colorimetry to the determination of small quantities of poisons (*e.g.*, arsenic, mercury, and lead), or of adulterants and impurities, and it can be applied to water analysis. Colorimetry is also finding increasing application in the field of metallurgical chemistry. The method is used in the steel industry to provide a rapid and accurate determination of carbon, manganese, titanium, vanadium, chromium, etc., in steel.

In view of the rapid progress made this book by Dr. Freund is particularly opportune, since it presents in a lucid form a general synopsis of the methods published in a great number of papers. It contains over one hundred formulas for colorimetric determination in bio-chemistry, medicine, food, and agricultural chemistry, water analysis, and the chemistry of metals, and should prove a valuable time-saver to the investigator and worker in these fields.

Translated by Frank Bamford, B.Sc. (Lond.), the book is published by the author, Dr. Hugo Freund, and the sole distributor in Great Britain is E. Leitz (London) 20, Mortimer Street, London, W. 1. Price, 10s. net.

Embrittlement of Hot Galvanised Steel.

THE problem of embrittlement in galvanised structural steel angles for electrical transmission towers is discussed and methods of quantitative testing for such embrittlement about punched bolt-holes are described in this publication. Data from a large number of test on 170 heats of Bessemer, duplex, and open-hearth steel in the as-rolled, pickled, and galvanised conditions with punched and drilled holes are also presented. The work is the result of an extensive study of embrittlement phenomena which had been of considerable concern to transmission tower engineers and consumers and producers of hot-galvanised steel products. A true understanding of the causes and cure of embrittlement was desired, and the problem was studied at Battelle Memorial Institute under the direction of a special committee of the American Society for Testing Materials.

The results are summarised and a brief history of the problem outlines the several testing methods used, and presents the results in a clear form with careful analysis and their interpretation. Apparently, in commercial structural steel embrittlement is confined almost solely to the largest size punched angles. Punching is the principal factor in embrittlement. Pickling, galvanising, the nature of the steel, and the temperature of testing play secondary, minor, or negligible rôles. Avoidance of punching in the heavy size angles is necessary and generally sufficient to avoid injurious embrittlement difficulties in present-day commercial galvanised structural steel angles. This publication, bound in heavy paper cover, and comprising 109 pages, may be obtained from A.S.T.M. Headquarters, 1315, Spruce Street, Philadelphia, U.S.A. Price, $1.

Effect of Magnetic Treatment on Age-Hardening of Quenched Steels and Alloys

Considerable experimental work on hardening metals magnetically has been carried out by E. G. Herbert, [1, 2, 3] and in order to test the results obtained, Yosiharu Matuyama has attempted to repeat these experiments, the results of which are published in a report[4] from which the following has been extracted.

In studying the age-hardening of a specimen, it is first necessary to measure the hardness at different points in order to determine the degree of variation. With this object x–y co-ordinates were taken, having the origin o at a point 2 mm. away from the left hole of the specimen, as shown in Fig. 1, and the hardness at ten points along the line parallel to the y-axis and 1 mm. apart from each other was measured, and, further, the same measurements at 18 series of points, the distance of each series along x-axis being 2 mm., were also made. The hardness was mostly measured by Vicker's hardness tester, using the 2 in./3 ocular and a 5–20 kg. weight. Hardness tests were made on a 0·6% carbon steel, which was quenched from 800° in water and left for two days at room temperature, and a 0·7% carbon steel, which was quenched from 780° in water and left for one day at room temperature. The results of these which are given, show that the local variation of hardness in quenched steels amounts to 4·6%, and that this variation becomes less as penetration is deeper from the surface.

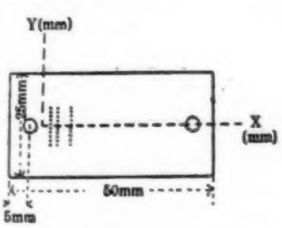


Fig. 1—Preparation of specimen.

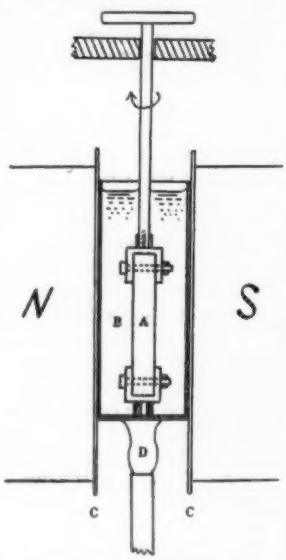


Fig. 2.—The apparatus used for treating specimens.

In the main experiment the specimen used was duralumin, Armco iron, carbon steel, high-speed steel, and K.S. steel, the dimensions of which were 50 × 27 × 7 mm. The magnetic treatment was made by an electro-magnet of the largest Weiss type, the current passed being 30–40 amps. The distances between the poles was about 32 mm., and the field between them about 6,000–7,000 gausses. The apparatus is shown in Fig. 2. A is a specimen placed in a water-bath B, which is insulated thermally from the magnetic poles N and S by asbestos plates C. The water in the bath can be heated by a gas-burner D.

The results of tests made by this experiment on the various materials mentioned are given in the form of curves. In each case tests were made on the material in a non-magnetically treated condition, as well as after being magnetically treated. In respect of duralumin, it is shown that hardness increases rapidly for some hours at the beginning, due to age-hardening; apart from this the magnitude of the fluctuations of the curves does not exceed 5–6%, which is within the local variation of hardness.

Curves from the results of tests on specimens of other materials cause the author to conclude that the magnetic treatment can have no effective influence on the hardness of non-magnetic or magnetic substances, and he endeavours to explain the results obtained by Herbert, who, in reports of his experiments, describes neither the local variation of the hardness in his specimens, nor the accuracy of the pendulum hardness tester. The author states that the accuracy of the pendulum hardness tester used by Herbert seems to be in no way superior to that of Vickers. Error may arise, when the specimen is magnetic, because certain parts of the pendulum are of iron, especially the steel ball and its holder, which are very near the magnetised specimen. To confirm the influence of these magnetic parts on the oscillation of the pendulum a test was made in which a pendulum hardness tester was used to measure the hardness of a standard glass plate, so arranged that a horseshoe magnet could be placed below the glass. Tests were made with and without the magnet, and, according to the results obtained, the hardness is increased from 6 to 10% by placing the magnet below the glass plate. The author also measured the hardness of various steels in the demagnetised and magnetised state, and found that the hardness was greater when the specimens were in the magnetised state. These increases are explained by the author as the effect of the magnetic force acting on the iron parts of the pendulum.

The ageing effect of the residual magnetism of a steel wire which underwent a single turn in a magnetic field was observed by Herbert, who noticed that the residual magnetism fluctuated with the lapse of time. The author claims to have repeated the same experiment without being able to confirm the results. Generally, the results of this experiment did not at all confirm Herbert's experiment.

[In view of the negative results obtained by Mr. Matuyama in this investigation, and in justice to the work done on the subject by Mr. Herbert, we publish the following correspondence.—EDITOR.]

October 20, 1932.

Dear Sir,—As you may have received a paper by Mr. Matuyama on the magnetic treatment of metals, I am sending you a copy of a letter which I have addressed to the University of Tohoku on this subject.

In seeking to reproduce experimental results of an unusual character, it would seem obvious that the experimental conditions should be closely reproduced, or at least not departed from in essential particulars, deliberately and needlessly.

In my original magnetic treatment, rotating the specimen while bridging a very narrow air gap in the magnetic circuit, the intention was to create a violent atomic disturbance by passing the specimen through an intense and highly distorted field. I have used this method in all subsequent experiments because—

It has never been known to fail.

It is the simplest treatment that could be devised.

It is applicable to specimens, including cutting tools, of every kind, irrespective of size or shape.

1 Herbert, *Journ. Iron and Steel Inst.*, **120**, 1929, 239.
2 Herbert, *Proc. Roy. Soc.*, **130**, 1931, 514.
3 Herbert, METALLURGIA, May, June, November, 1931.
4 The 288th report, Research Inst. of Iron, Steel, and other metals.

Mr. Matuyama has adopted an essentially different method which—

Is lacking in simplicity.

Is not likely to be effective, and

Even if effective could have no practical application. Negative results produced under such conditions are irrelevant.

For investigating the effects of magnetic treatment, Mr. Matuyama had access to two hardness testers, the Herbert pendulum as used in my experiments, and the Vickers machine. He chose the Vickers machine. The essential difference between these two systems is that the pendulum measures hardness under load, and takes account of both elastic and plastic deformation. The Vickers' machine measures plastic deformation only. It has been found capable of revealing hardness changes produced by suitable magnetic treatment, but is incapable of indicating changes in the elastic properties of metals, and there is reason to believe that such changes are principally, though not exclusively, involved.

Mr. Matuyama has discovered that metals are subject to local variations of hardness. It might be inferred from his paper that he would therefore advocate the abandonment of hardness testing as a method of investigation. The only alternative would be to take such precautions that the local variations, which are always present, do not vitiate the results.

For some years past it has been my endeavour to impress on those who are concerned with hardness the necessity of taking such precautions—namely, in the case of all commercially hardened work, the use of the Cloudburst multiple-test covering the whole surface ; or, where this method is not applicable, as in metallurgical research, the use of a systematic process of averaging. The precautions I have adopted are indicated in the enclosed letter, and it will be found on consideration that these precautions are essential, that they are adequate, and that no other precautions are possible.

The periodic fluctuations which are set up by the mechanical, thermal, or magnetic disturbance of metals have nothing whatever to do with local variations of hardness.—Yours faithfully,

EDWARD G. HERBERT.

Barlow Moor Road,
West Didsbury,
Manchester.

[COPY.]

The Principal, September 1, 1932.
Tohoku Imperial University,
Sendai, Japan.

Sir,—I have been favoured with a copy of a paper entitled, "On the Effect of Magnetic Treatment on the Age-hardening of Quenched Steels and Alloys," by Yosiharu Matuyama. As the effect of this paper is to discredit my work I shall be glad if you will publish this letter and give it the same publicity as is given to the paper above mentioned.

1. The whole of my magnetic experiments have been made with magnets having an air gap 3 mm. wide, the specimen being placed in contact with the pole pieces, bridging the gap, and being rotated in that position. The strength of field in the gap was from 6,000 to 27,700 gauss.

Mr. Matuyama has rotated his specimen in the centre of a wide air gap in a field of 6,000–7,000 gauss. I have made no experiments under conditions resembling those used by Mr. Matuyama. I should not expect such experiments to succeed.

2. The effect of local variations of hardness in metals has been specially studied by me, and I have invented a hardness test, the "Cloudburst," for revealing such variations. Local variations always exist and must be taken account of in research work of every description involving single-point hardness tests. The following precautions are necessary, and are always taken by me :—

(a) Adequate preparation of surface.

(b) Selection of specimens of adequate uniformity, and rejection of any that are not uniform.

(c) Averaging of a sufficient number of individual readings to eliminate any effect due to local variations.

3. The effect of the field of magnetised specimens on the pendulum readings has been carefully investigated, with the following results :—

(a) The specimens used in my experiments are generally not larger than 15 mm. × 15 mm. × 2 mm. The field of a magnetised specimen of this size has no measurable influence on the pendulum. Nevertheless, the precaution is always taken of keeping the plane of oscillation of the pendulum in unvarying relation to the direction of polarity of the specimen throughout the experiment. If the field of the specimen had any influence on the pendulum, it would therefore be a constant and not a variable influence, and would not affect the results.

(b) A heavy magnetised specimen, say, 30 mm. × 30 mm. × 15 mm., if placed on a non-magnetic support, such as a glass plate, is capable of influencing the rate of swing of the pendulum if the direction of polarity coincides with the plane of oscillation of the pendulum. The time hardness is decreased by 5 to 7%.

(c) A magnetised specimen as in (b) on a non-magnetic support, if placed with the direction of polarity at right angles to the plane of oscillation of the pendulum, does not affect the rate of swing.

(d) A magnetised specimen, if placed on a heavy iron support, so that its external field is short-circuited, does not affect the rate of swing in any position.

It is my practice when testing magnetised specimens to provide against any influence of the field by placing the specimen on a heavy iron support, with the direction of polarity at right angles to the plane of oscillation, and to maintain this relation throughout the experiment. The results are in no way influenced by the field of the specimen.

4. For testing very large magnetised specimens, pendulums of non-magnetic material can be obtained through the usual channels.

5. My hardness measurements are made with the pendulum. My results can be, and have been, reproduced by other workers using the pendulum. They have also been reproduced by other tests, including the Vickers. Nevertheless, I can take no responsibility for the disabilities of any hardness testers other than those used in my experiments.—Yours faithfully,

E. G. HERBERT.

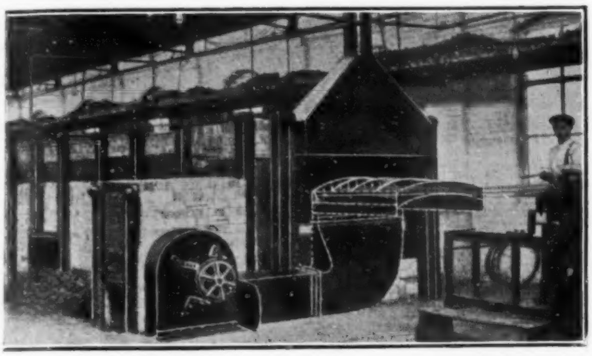
[We understand that Mr. Herbert has engaged in further research on this subject, in which he has traced the ageing changes following the mechanical, thermal, and magnetic disturbance of metals starting from the purest obtainable gold, nickel, and iron, up to hardened tool steel. The results of this research, he claims, confirm all those from his previous investigations on the subject. It is also of interest to note that high-speed twist drills have been submitted to a diversity of magnetic treatments, including simple rotary treatment, applied both cold and hot, stabilising at a maximum and at a minimum phase of the hardness fluctuations, with different strengths of field This has been done in the expectation, which was partly realised, that if one or more of the selected treatments proved beneficial, others would be deleterious to the performance of the drill. In a series of drilling tests carried out under similar conditions, both before and after the drills had been subjected to magnetic treatments by Mr. Herbert, the results on the whole indicate a substantial improvement in their drilling capacity after treatment, while certain specific treatments were in a marked degree successful in improving the performance of the drills. We understand that Mr. Herbert will, in further experiments, concentrate on the successful treatments in an endeavour to improve on the results already obtained.—EDITOR.]

Steel Wire Annealing

By Richard Saxton.

The two principal methods of annealing steel wire are briefly described, and the importance of the cooling-off process is emphasised because of its influence on the properties of the material.

IN the annealing of steel wire, the quality of the material and the purpose for which it is intended govern the heat-treatment given. Whilst raising and maintaining the heat is practically a mechanical operation, the subsequent cooling-off requires great care, for any variation in this produces a variation in the structure, with consequent irregularity in the temper of the material.



Courtesy of the Incandescent Heat Co. Ltd.

Fig. 1.—Ten-hole patenting furnace, complete with air-blast quenching plant.

When the furnace and contents have reached the temperature desired, time has to be allowed for what is termed soaking—that is, allowing the heat to thoroughly permeate the material. This soaking time is the period between the arrival at the required temperature and the commencement of the cooling process. As with the latter, any curtailment of soaking time results in a harder material and smaller grain formation.

The two principal methods of steel-wire annealing are known as the common (in which mild steel is annealed in bulk) and the patenting or tubing process. In the latter, each wire receives separate heat-treatment, and the process is such that whilst annealing it also exerts a toughening effect upon the material being treated. This process is a continuous one, 20 to 40 wires being treated at the one operation, and it is the only process in use for high-carbon steel annealing intended for the manufacture of high-tensile ropes. The illustration Fig. 1 shows a furnace for annealing high-tensile wire of this kind.

Though the fundamental object of annealing may be said to be the softening of the material, the changes which take place in the structure whilst undergoing heat-treatment are little known. It is possible, by curtailing or prolonging the cooling-off process, to produce a wide variety of grain, with resultant temper. The longer the cooling-off process is maintained the larger the grain and the greater the ductility, but there is a point beyond which, if the process is prolonged, the material will be found to have too coarse a grain for cold-working as in wire-drawing.

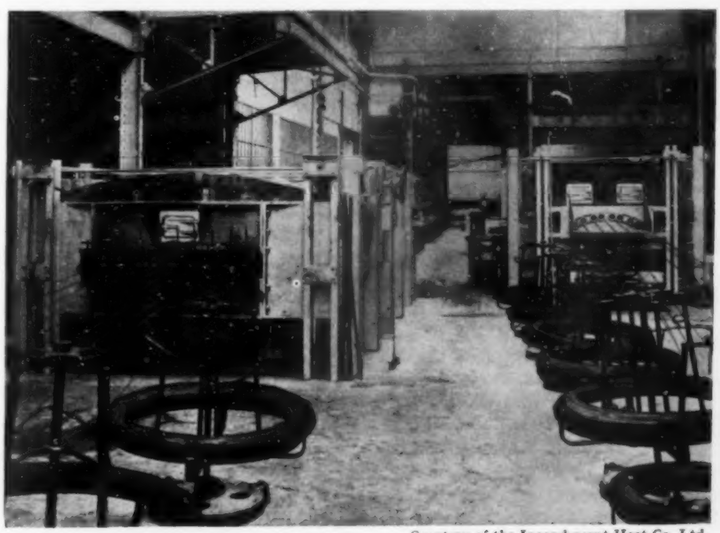
In the ordinary or common method of annealing wire, a number of coils are placed in a suitable pan, which is then sealed and placed in the furnace. By this method the quality desired is known as dead-soft, the material usually being intended for drawing smaller. A further object of this treatment is to eliminate or release the stresses produced by previous drawing.

During the heating process the first 100° has only a slight effect on the wire, but this increases as the temperature rises. At about 560° C. the material commences to undergo recrystallisation; at 620° the effects of drawing or cold-working are totally eliminated, but the material at this stage is in a state known as globularised pearlite, a condition in which, if allowed to cool off, it would be unsuitable for further cold work.

In order to convert into suitable material, the temperature must be raised to 800/900° C., and maintained at this point for some time, in order that the requisite change in structure is able to take place.

By raising and maintaining at this temperature, the material is converted into what is known as austenite. The subsequent cooling-off converts this into pearlite, a structure composed of alternate layers of ferrite and cementite. The arrangement of these layers depends upon the orientation of the austenite grains from which they are formed, and as each individual grain of austenite is oriented in all directions, the direction taken by the plates varies.

Pearlite may be said to consist of a number of grains, each made up of alternate plates of ferrite and cementite, and the course taken by the plates in each grain when submitted to the drawing or reducing process, is entirely independent of that of any other grain. It is due to this arrangement of ferrite and cementite that pearlite owes its properties.



Courtesy of the Incandescent Heat Co. Ltd.

Fig. 2.—Ten-hole wire patenting furnace in operation.

The width of the plates varies with the speed of cooling. Slow cooling produces large plates of a ductile nature, whilst rapid cooling produces small thin plates of a very hard consistency.

The patenting or continuous process is more costly than

the common, requiring a larger plant to operate, such as is shown in Fig. 2, which is a recent installation. The bulk of the material treated by this method is steel intended for high-strain work, and having a carbon content of from 0·50 to 0·90%.

In this method the material is heated to a temperature of between 950° and 1,050° C., and after being maintained at this heat for a time is allowed to cool off in the air or molten lead. The effect of this high temperature is to remove any stresses caused by previous working, to reduce the heterogeneity of the material, and to produce a homogeneous grain.

Within limits, the exact temperature to which the work is heated has little effect on the finished material, but the method of cooling-off is important. Whilst structural differences between lead and air-cooled material are not apparent, there is a deal of difference in their properties. Wire made from lead-cooled material is the superior in mechanical properties, but due to the difficulties in maintaining the lead bath at an efficient working heat, the air-cooled method has a wider adoption.

It is impossible to obtain torsional and tensile properties required in a rope wire by a final heat-treatment. These can only be obtained by a preliminary treatment capable of producing a structure which can be improved by the drawing operation. It will therefore be seen that the material required in suitable annealed wire is one with a fairly large homogeneous grain, which, whilst responding to the plastic deformation of the metal, will also successfully resist the fatigue stresses set up during the process of reduction.

The illustration shows a 10-ton charge of wire about to be loaded into the furnace. This is the method used in mild steel annealing, each pan holding from 10 to 15 cwts. of material. The charge is subjected to a heat of from 700° to 850° C. for a period of 12 hours and then withdrawn. The action of withdrawing is made to draw a further charge into the furnace from the opposite side.

Spring Steel Wire made of Mild Steel.

THE chief difficulty in making spring steel wire of mild steel is to get uniform strength properties in the rolled product. As H. Wiesecke states in *Stahl und Eisen*, 1932, pages 433-439, observations made in practical service showed that the factors affecting the uniformity of product are thickness of wire, rolling and cooling rates at the wire mill, and temperature of the wire in the last pass and during reeling. The results of these observations are shown in several diagrams. Further investigations were made into the factors influencing the hardening process—viz., chemical composition, quenching temperature, and temperature of the quenching medium (water). Carbon in very small quantities seems to have a supercooling effect. Manganese acts in the same way provided that the quantity present exceeds 0·5%. The segregations present in the original ingot tend to increase the strength in proportion to the degree of segregation. The numerous inclusions apparently have an inoculating effect.

Of a basic Bessemer steel containing carbon 0·065% and manganese 0·54%, and an open-hearth steel containing carbon 0·075% and manganese 0·34%, the strength properties were determined after quenching from 700° to 1,100° C. The Bessemer steel had a well-defined critical point, the increase in strength being 16 tons per sq. in. when quenched from temperatures between 860° and 940° C. The strength properties of both steels decreased when quenched from temperatures between 1,020° and 1,080° C. This fact can be ascribed to the effect of the surrounding atmosphere, the high temperature enhancing the diffusion rate and absorption of gases, promoting chemical reactions and grain growth, and lowering the strength of the outside layers of the crystals.

At a quenching temperature of 900° C., increasing the temperature of the water from 10 to 65° C. resulted in decreasing tensile strength and stretch limit by about 4 tons per sq. in. The mill scale was also found to have a harmful effect upon the strenth when allowed to act for a sufficiently long period. A large-scale experiment, considering all the factors which are responsible for the uniformity of product, showed that, contrary to the common opinion, an open-hearth steel containing carbon 0·06%, manganese 0·34%, phosphorus 0·039%, and sulphur 0·048%, is well suited as raw material. Some diagrams show the effect of wire thickness upon the increase in strength in the cold-drawing operation.

Progress in the Manufacture of Railway Rolling-Stock Parts.

THE railway rolling-stock engineer is continually looking out for means whereby he can take full advantage of the developments which take place in manufacturing methods of production.

One of the recent examples of this has been the increasing adoption of solid rolled wheels for railway rolling-stock, as is evidenced by the preparation of B.S. Specification No. 468, Solid Rolled Wheels and Disc Wheel Centres, which has recently been published.

The policy which has been adopted in a number of the specifications relating to railway rolling-stock materials has been followed in that duplicate specifications are provided for solid rolled wheels. One of these specifies a chemical analysis and covers wheels for carriages and wagons. In the other, however, no chemical analysis is specified, and it is restricted to wagon wheels only. A specification for rolled disc centres for carriages and wagons is also included.

These specifications were prepared by a representative committee constituted as shown below, and which is fortunate in having as its chairman Sir Seymour Tritton, the prominent consulting engineer to the Indian Railways :—

Sir Seymour Tritton, K.B.E. (Chairman) ; Mr. H. N. Gresley, C.B.E., and Mr. C. B. Collett (representing Railway Companies of Great Britain) ; Brig.-Gen. Sir Brodie Henderson, K.C.M.G., C.B. ; Major C. E. Williams, O.B.E. (Crown Agents for the Colonies) ; Mr. A. C. Carr (Sir John Wolfe Barry and Partners) ; Mr. D. Dawson (Egyptian State Railways) ; Mr. F. W. Harbord, C.B.E. ; Mr. H. J. Skelton (Messrs. H. J. Skelton and Co., Ltd.) ; Mr. G. Baker (Messrs. J. Baker and Co. (R'tham) 1920, Ltd.) ; Mr. E. Dixon (Messrs. T. Firth and John Brown, Ltd.) ; Mr. F. Leach (English Steel Corporation) ; Mr. J. O'Connor and Mr. A. Good (National Federation of Iron and Steel Manufacturers) ; Mr. E. H. Saniter (Steel Peech and Tozer, Ltd.) ; Mr. C. E. Squire and Mr. A. Williamson (Laminated Spring Makers' Association).

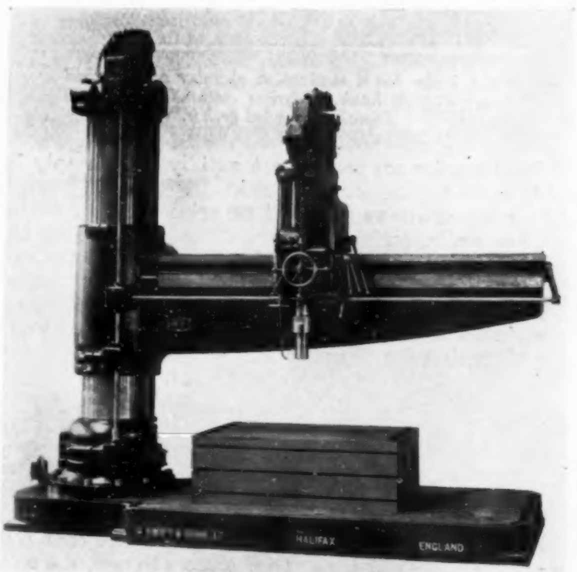
The specifications have been drafted along parallel lines with the corresponding B.S. Specification for Railway Tyres—*i.e.*, requirements are included governing quality of material, manufacture, workmanship, and mechanical testing. One of the most difficult points that emerged in the preparation was that of arriving at suitable tolerances on the thickness of the web of the wheels. Whilst appreciating the difficulties with which the manufacturer is faced in rolling the somewhat complex outline of a combined solid tyre and wheel, the railway engineers were faced with the necessity of ensuring that each wheel should as far as practicable be of uniform weight. With increasing speeds, the elimination or, wherever possible, the reduction to a minimum of all out-of-balance forces becomes of primary importance. The clause in the specification dealing with this point has attempted to meet the engineer, and at the same time represents consistent and good manufacturing practice.

The specification is of interest to all engineers responsible for the upkeep and design of railway rolling stock as well as to those interested in the manufacture of such wheels. Copies can be obtained from the Publications Department, British Standards Institution, 28, Victoria Street, London, S.W. 1 ; price 2s. 2d. post free.

Recent Developments in Tools and Equipment

CENTRALISED CONTROL RADIAL DRILLING MACHINES.

ALTHOUGH machine-tool designers have recognised the need for increased rigidity, in order that machines will function successfully at high operating speeds without vibration difficulties, considerable attention has also been directed to the development of designs that reduce unproductive time. The solution of this problem is at least equal in importance to the problems associated with higher cutting speeds, which have been solved by the introduction of modern cutting materials. It is true, of course, that the major part of the unproductive time of a machine is concerned with the tools that are used in it, but convenient location of controls and their easy manipulation have a considerable influence in reducing the time during which a machine is unproductive.



12-ft. radius drilling machine, representative of the range.

This factor has been appreciated in the range of radial drilling machines manufactured by George Swift and Sons, Ltd., Claremont Ironworks, Halifax. In these machines every control is on the saddle, placed in the most suitable position for the operator, and enabling maximum output to be obtained with minimum power consumption, because much of the unproductive time of the machine is eliminated. In addition, the machines are of simple and rigid design, and they operate at speeds and feeds suitable for every requirement.

The accompanying illustration shows the 12-ft. radius machine, and is representative of the range, which is built in sizes from 4 ft. 6 in. to 12 ft. radius. All the machines are of sturdy construction. The baseplate is well ribbed and of adequate depth. It is of ample size, with a good working surface, and the tee-slots are machined from the solid. The pillar and sleeve are very rigid, of large diameter, and ground to make a perfect working fit. The sleeve is mounted on ball and roller bearings at top and bottom, so as to swivel by finger pressure. A feature of interest is the channel around the top face of the baseplate to collect lubricant which drains into the sump and settling tank at the pillar end.

The box-section arm is stiffened by bridge formation ribbing to give a design of more than usual strength. The upward thrust is taken on a vee, and twin ways are provided on top for the saddle. The elevating motion of the arm is by separate reversible motor, mounted on top of the sleeve, driving the elevating screw through reduction gearing, safety trips being fitted to prevent overrunning.

Mounted on adjustable roller bearings, the saddle is traversed easily by hand-wheel. The movement is such that finger pressure only is needed. Every control is on the saddle, and the controls are conveniently grouped to be within easy reach of the operator.

The 24-in. diameter column model is locked by means of a separate motor located at the top of the column, by which the saddle is locked to the arm, the arm to the sleeve, and the sleeve to the pillar. This motor is controlled by push buttons on the saddle, and separate adjustments are provided to each motion. On the 15-in. and 18-in. diameter column models the lock is by single lever located on the saddle, but a power lock, with push-button control, can be fitted if desired.

A special high-carbon steel forging is used for the spindle, which is mounted on ball journal and thrust bearings. The driving portion is six-splined, and the end bored standard Morse taper. Sliding gears made of heat-treated steel provide twenty-four spindle speeds. They are mounted on splined shafts, which run on ball bearings. By a movement of a lever, twelve slow speeds are available for tapping, with twelve corresponding high speeds for withdrawing the tap. Sliding gears and a final worm reduction provide nine feeds. The worm-wheel embodies an expanding ring friction clutch, which when disengaged allows the spindle to be rapidly moved into any position.

Standard single-speed vertical spindle motors are used both for drive and elevating motion, for either A.C. or D.C. The drilling motor is non-reversible, and the elevating motor is reversible. The control of these motors is by push buttons conveniently located on the saddle. These push buttons operate a contactor panel, in which is carried the control gear.

Built to meet the requirements of modern practice, this range of radial drills provides a good example of the refinements now incorporated, together with sturdy construction to facilitate production under the most arduous and exacting conditions.

SUSPENDED COMBUSTION CHAMBER WALLS.

Latest Scientific Principles of Design and Construction.

IT is well known the ordinary solid firebrick wall is now obsolete for water-tube boiler combustion chambers with high-duty mechanical stoker or pulverised-fuel equipment, and is being replaced by the suspended wall, a subject of particular interest also for the iron and steel industries.

In general, a firebrick combustion chamber wall is deteriorated because of the slag which adheres to the surface, and consequently the simple solid wall is now out of date for two reasons. First, it soon becomes very hot, and the molten slag adheres easily and is able to exert the maximum destructive action. Also repairs can only be carried out by taking down the whole wall above, since, of course, the lower portions, mostly affected, have to carry the weight. This emphasises another serious disadvantage of the solid wall, the fact that almost every brick is subjected continuously to a degree of pressure,

because of the material above, according to its position in the wall, this action being very severe in the lower parts of the setting.

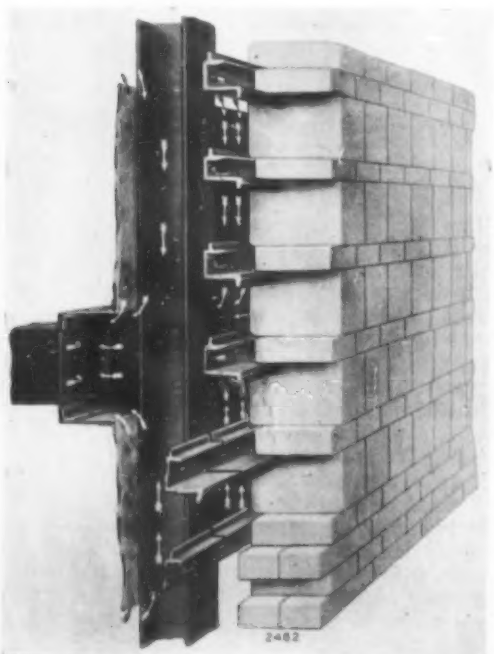
Modern practice consists, therefore, in using the "suspended wall" that is built up of a series of firebrick blocks each of which is carried separately by a steel framework behind.

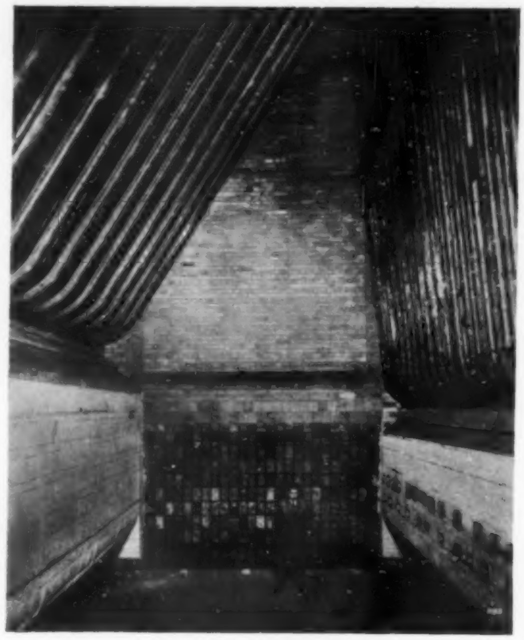
In this connection of great interest are the latest designs of the "Bigelow" standard air-cooled suspended wall, manufactured in Great Britain, along with "Liptak" suspended arches, by Liptak Furnace Arches, Ltd., 38, Victoria Street, London, S.W. 1. These have just been fitted, for example, in the boiler plant of the remarkable new Ford works, at Dagenham, Essex, which is on the most advanced lines.

The design consists of a steel framework to which are bolted a series of steel castings or carriers, with a flange portion to which high-grade large firebrick blocks are attached, made with an indentation or groove at the top, so that they hang suspended side by side from the castings. On these lines a wall can easily be built of any shape or size, and between the narrow spaces above and below each suspended block, left to allow for addition or withdrawal, is built ordinary firebrick, while a batter of weathered fireclay is used for finishing. As a result the wall, which is 11 in. standard thickness, is of true "suspended" type, each block being carried entirely and quite independently by the steel framework. No pressure, therefore, due to weight is exerted and each individual block is easily replaced without affecting the rest of the wall. Further, in the space behind the wall, between the steel castings and the framework, covered by any simple type of outer casings, such as sheet steel lined with asbestos, a current of air is passing continuously, either by natural circulation or in conjunction with an induced or forced draught circuit, with the warm air used for combustion. Consequently, the molten slag does not adhere to the brickwork because the air circulation, aided by the heat transmission properties of the metal framework maintains the temperature of the face of the wall below the fusing temperature of the slag, giving a great increase in the life as compared with the ordinary solid wall which soon heats up and is rapidly deteriorated by slag.

The net result, therefore, is a revolution in maintenance costs, because the deterioration is enormously reduced and

Indicating the principle of the Bigelow suspended furnace wall.





No. 1 boiler house combustion chamber at Thornhill Power Station, having Bigelow suspended walls and Liptak suspended arches.

any local repairs are carried out rapidly and cheaply by merely replacing one or two bricks.

The most extensive practical experience is represented by these walls, and a number of modifications of the standard design are also available for special conditions, while it will be noted the wall is of simple unit construction with three parts only,—that is, the steel casting, the large firebrick block, and the small filler brick—enabling every type of combustion chamber wall to be built easily and quickly.

Colouring Foundry Patterns.

THERE are at the present time a number of conventions in use in this country in regard to the marking and colouring of patterns, the object of the markings being to indicate whether the article to be cast is to be in ferrous or in non-ferrous metals, to indicate the position of cores, the seats of core prints, stop-offs, and whether and on which surfaces machining is required. In view of the diversity of present practice, it is clear that it will be of great convenience to the industry to have a uniform practice adopted so that all patterns reaching a given foundry will be marked in the same kind of way. The primary object of varying the colour is to convey information to the foundry that cannot be mistaken. Not only is this of value in determining the metal of which the casting is to be made, but the indication of surfaces to be machined enables moulding methods to be adopted that will ensure the best surfaces for this purpose.

A representative committee was formed and the matter very fully considered, with the result that a specification has now been issued standardising the colours for the various purposes mentioned.

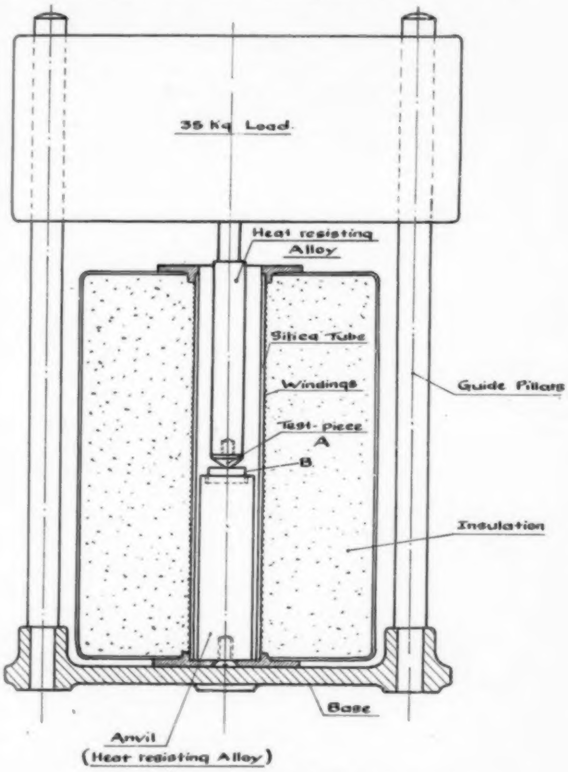
The scheme adopted has been chosen so as to interfere to the smallest extent possible with current practice in the country, but as the practice varies it obviously is necessary for some people to make changes in order to line themselves up with the specification. There can be little doubt, however, that the gain resulting from the adoption of a uniform convention will be sufficient to justify the small amount of trouble likely to be involved in certain cases in putting it into operation.

Copies of this specification (No. 467-1932) may be obtained from the Publications Department, British Standards Institution, 28, Victoria Street, London, S.W. 1. Price, 2s. 2d. post free.

THE HARDNESS OF METALS AT HIGH TEMPERATURES.

A METHOD for determining the true hardness of metals at high temperatures, which enables the results to be expressed as Brinell hardness, has been developed by Mr. J. Ferdinand Kayser, Chief Metallurgist of Darwin's, Ltd., to whom we are indebted for the following details.

The sample to be tested is in the form of a small cone, "A," with an included angle of 120°. This rests on an anvil, and is submitted to a load of 35 kilogs. for a period of ten days. The anvil, cone, and plunger are surrounded by a small electric resistance furnace, and can be maintained at any desired temperature up to 1,150° C., the temperature being controlled by any of the usual types of temperature control. The anvil cap, "B," is made from a hard, heat-resisting metal containing approximately 60% nickel, 20% chromium, and 7½% aluminium. Provision is made for maintaining an inert atmosphere desired.



Apparatus for applying the method.

Under the combined effects of pressure, time, and temperature the apex of the cone flattens out, and the area of contact between it and the anvil face steadily increases. Equilibrium is usually reached in about 100 hours, but it is advisable to allow a considerable factor of safety, and the test is maintained for ten days. The hardness number is derived exactly as in the Brinell test—*i.e.*, the area of the flattened surface on the cone in square millimetres is divided into the load in kilogrammes. Above 700° C. practically all metals, with the exception of tungsten carbide and a few peculiar alloys which depend for their hardness upon the presence of compounds of aluminium with a metal of the iron group, appear to have a Brinell hardness considerably less than 10. In the case of an alloy containing 28% chromium and 0.3% carbon, the Brinell hardness at 800° C. was found to be 1·5. The creep stress of that metal at 800° C. is approximately 700 lb. per sq. in. (0·50 kilogs. per sq. m/m.), and if one assumes that the relationship between Brinell hardness and ultimate strength is the same at all temperatures, one would anticipate a Brinell hardness of approximately 1·5, but previous investigators have always found higher values. Whilst at first sight it may appear inaccurate to express the figures obtained with this machine as Brinell hardness, experiments have shown that if instead of carrying out the hardness test as in the Brinell method the test-piece in the form of a cone with an angle of 120° is pressed against a hard steel plate, the pressure per square millimetre on the flat surface thereby formed on the cone is in close agreement with the Brinell hardness numeral determined by the orthodox method.

GOLD MINING IN WESTERN AUSTRALIA.

PROSPECTORS AGAIN IN THE FIELD.

THE gold-mining industry of Australia is benefiting more than that of any other part of the world from the recent rise in the value of gold. The principal gold-mining State in the Commonwealth is Western Australia, which produces about 85% of the total gold yield of the entire continent. Gold has been proved in more or less payable quantities over the greater part of it.

The normal value of gold is £4 4s. 11d. per fine ounce; owing to adverse exchanges the value in Australian currency at the present time is £7 10s. 0d. per fine ounce. This increase has helped to direct a great deal of attention to the gold-mining industry.

A mining inspector of many years' experience estimates that there are 8,000 "shows," as they are called in Australia, where gold has been proved to exist. The majority of these, of course, had been abandoned up to two years ago, but a great many are now being revived, and promising new propositions are being opened up, mainly by small working parties. The public batteries are in most cases booked well ahead with parcels of ore from these potential mines.

Some very fine individual rewards have been secured, either on the surface or with very little development; the nugget found on the surface at Larkinville, for instance, weighing approximately 1,150 oz. Another rich surface strike at Bardoc gave 928 oz. from 10 tons. And these places are over 100 miles apart. Again, on the Murchison fields, 300 miles further north, a prospector during the last twelve months has secured 2,419 oz. from 20 tons.

As an example of some of the returns secured by working partnerships from payable mines using their own machinery, the case of Messrs. Barr and Clements, of Southern Cross, may be mentioned. During the past twelve months they have raised from their own mine, and treated at their own battery, 758 tons for 1,710 oz. Hill 60, at Mt. Magnet, produced in the period 4,435 tons for 1,694 oz.

Many abandoned "shows," which had given good results up to 30 years ago down to water level, are now being worked again, and it is in connection with these that a few hundred pounds would often facilitate the development at a greater depth. In many cases these abandoned shows were worked to less than 200 ft., and at that time it meant steam-boilers, engine and pump, and steam-engine drivers. To-day the crude-oil-engine, running practically without attention and at much less cost, is being used.

A typical example of the richer "shows" that were abandoned is one on the Murchison goldfields, which up to 30 years ago was worked down to 180-ft. level, 2,146 tons being crushed for a total of 6,212 oz., showing a shute of gold that was well worth developing to greater depth. This has only recently been taken up by a couple of working miners, who have to depend on machinery merchants for credit to provide the pumping plant.

Most of the activities of the last couple of years have been concentrated in the Southern half of the State, but the Northern half, too, has possibilities.

While Western Australia is successfully growing large areas of wheat, and its sheep flocks now total over 10,000,000, it is fortunate in being able in these days of depression to fall back on its auriferous areas.

Business Notes and News

Steelworks Development Scheme.

The directors of the Skinningrove Iron Co., Ltd., have taken over the active management of the Skinningrove iron and steel works, and have decided on a scheme of development. In order that the new policy can be operated effectively, and to enable the technical equipment to be overhauled and supplemented where necessary, the Company has ceased rolling until March of next year. The Company has retained the services of Mr. C. G. Atha, who was until recently one of the managing directors of Messrs. Stewarts and Lloyds, Ltd. as consultant to advise on the technical staff. Mr. J. H. Skelton, late of Messrs. H. J. Skelton and Co., Ltd., Royal London House, Finsbury Square, London, E.C. 2, has been appointed to undertake the re-organisation and supervision of the Company's selling side, and has already joined the staff. To enable the new policy to be effectively operated the Company ceased rolling on Saturday, November 5, and expects to renew steel manufacture on Monday, March 6, 1933. Stocks will be maintained to avoid as far as possible inconvenience to the Company's customers.

The Copper Duty and Empire Supplies.

Some particulars of the Conference, held at the Board of Trade, with regard to Empire copper, were given recently by Mr. Hore Belisha, Financial Secretary of the Treasury. Some 90% of the whole copper industry was represented at this Conference and an agreement reached. In order to ensure the progressive change-over from non-Empire to Empire copper, the consumers agreed to give every possible assistance to the producers in an endeavour to satisfy the consumers' requirements in respect of quality; and, further, they agreed, as far as lies in their power, to purchase from Empire producers in preference to non-Empire supplies. The assistance offered will include the maintenance of a technical committee for the study and discussion of problems arising, on which representatives of the producers will be welcomed. The principle that the United Kingdom consumers should not be at a disadvantage compared with foreign consumers was accepted and an undertaking given.

Coal-oil Fuel.

Reference to the coal-oil fuel, which has been successfully tried in the Cunard liner, *Scythia*, was made by Professor J. S. S. Brame, of the Royal Naval College, Greenwich, in an address delivered before the Chemical Engineering Group of the Society of Chemical Industry recently. For use on land, he stated, it seemed unlikely that coal-oil mixtures would compete with mechanical stokers or with pulverised coal. No opportunity, he suggested, should be overlooked which might increase the use of home-produced fuel, but it was necessary to guard against any exaggerated ideas of what the introduction of coal-oil fuel might mean to the coal industry. Any extended use of such fuel for the immediate future lay entirely in its application for steam raising aboard ship. Taking the merchant navy and the Royal Navy together, and assuming that nothing but coal-oil fuel were to be used, the increased demand for coal would amount to approximately 1,000,000 tons, which was a very small increment in our total coal output of about 240,000,000 tons a year. Although the possibility of using colloidal fuels in oil engines had been foreshadowed, it was safe to say that for the present any such development was many years ahead.

Research Appointments.

The Secretary of the Department of Scientific and Industrial Research announces that the Lord President of Council has appointed Professor Alfred Fowler and Sir Clement D. M. Hindley to be members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research in place of Sir J. Alfred Ewing and Sir David Milne-Watson, who have retired on completion of their terms of office. Professor Fowler is a Past-president of the Royal Astronomical Society, Yarrow Research Professor of the Royal Society, and Professor of Astro-Physics in the University of London at the Imperial College, South Kensington. Sir Clement Hindley, a civil engineer and a member of the Council of the Institution of Civil Engineers, is a recognised authority on Indian matters, especially those relating to railways and port administration. It is further announced that Sir Harold Hartley, Vice-president of the London, Midland and Scottish Railway, and Director of Scientific Research of that railway has been appointed Chairman of the Fuel Research Board, and that Dr. N. V. Sidgwick, of Oxford, is to be Chairman of the Chemistry Research Board of the Department of Scientific and Industrial Research in place of the late Sir Richard Threlfall.

New Degreasing Plant for Gas Companies.

Degreasing plant, in which is used the non-inflammable solvent trichlorethylene, has proved so successful in the motor, textile machinery, and other engineering trades for the removal of all traces of grease, that a further development has recently been effected. This comprises a new model, known as type D which has been designed to eliminate the laborious cleaning processes previously associated with the renovation of gas cookers. By means of this new method, it is only necessary to strip the cooker of all removable parts, remove the slag wool, and load the main body of the cooker and all the parts, except the slag wool, into the plant. After five minutes they can be lifted out free from grease and dry. This plant is a product of Imperial Chemical Industries, who offer gas authorities and stove shop managers the advice of their technical staff on new methods of removing grease and carbon.

A Sulzer-Armstrong, Whitworth Agreement.

We are informed that Sulzer Bros. (London), Ltd., have entered into an agreement with Sir W. G. Armstrong, Whitworth and Co. (Engineers), Ltd., to manufacture certain specialities exclusively for Sulzer Bros. at Scotwood Works, Newcastle-on-Tyne. The firm of Armstrong, Whitworth are already acquainted with Sulzer designs and production methods, having manufactured Sulzer Diesel marine engines under licence for over 12 years, and they also hold a licence to build Sulzer traction Diesel engines.

Centrifugal pumps, Diesel engines, refrigerating plant, etc., will be manufactured from drawings supplied by Messrs. Sulzer Bros., Ltd., of Winterthur, and all the advantages of the accumulated experience of the latter firm will be available. To give further assurance that quality and workmanship will also be of the same high standard the production will be under the immedaite supervision of inspectors trained at the Winterthur Works.

This arrangement, however, does not preclude the London firm of Sulzer Bros. from supplying machinery manufactured in Switzerland as hitherto, but the fact that they are now in a position also to supply British built plant will not only enable them to retain the support of valued customers in this country, but will tend to add to their number in view of the demand for British machinery.

Foundry Practice Awards.

The Council of the Institute of British Foundrymen have every reason to be pleased with the response to the first appeal for students to sit for the City and Guilds of London Certificate Examinations in pattern-making and foundry practice. The new scheme was only instituted a year ago, in which a three-years' course is laid down, and permission from the Council of the Institute was necessary before students could sit for the certificate examination. In all 74 sat, and 42 passed with certificates. The winner of the Guild's bronze medal for foundry practice was Mr. T. R. Walker (B.A.Camb.), who is branch secretary of the I. Brit. F. at Sheffield. For pattern-making, Mr. G. K. Simpson, of Rugby, was awarded the silver medal for the final examination, and Mr. J. G. Rees, of Sheffield, the bronze medal for the intermediate paper.

Personal.

Mr. James C. Colquhoun, M.B.C., has been appointed chairman and Messrs. E. Andrew Mearns and Bernard P. R. Parsons managing directors of the Manganese, Bronze, and Brass Co., Ltd., following the regrettable death of the Company's managing director, Mr. James C. Gray, O.B.E.

J. Bigwood and Son (1930), Ltd., Wolverhampton, have been appointed representatives of the Republic Steel Corporation, Youngstown, Ohio, for the sale of that Corporation's foreign rights and machinery for the manufacture of electric weld tube and pipe under patents owned and controlled by the Corporation in all countries of the world, excluding the U.S.A. and Canada.

Mr. G. N. Guest, late managing director of Messrs. Hollings and Guest, Ltd., hydraulic engineers, and also of Messrs. Hands and Sons, Ltd., power-press makers, has recently joined Messrs. Tangyes, Ltd., Cornwall Works, Birmingham, in connection with the hydraulic machinery side of their business.

Some Recent Inventions.

Electric Welding Machines.

IN electric spot-welding operations, particularly with bulky work-pieces, it is frequently advantageous to operate the electrode either by vertical or horizontal movements, and the object of a recently improved machine is to enable both these movements to be effected in one machine. The improved design incorporates a vertically movable slide, a horizontally movable electrode carrier mounted on the slide, toggle or other suitable mechanism for actuating the electrode carrier, and common means for operating either the slide or the carrier. The arrangement is such that when the slide is locked to its guide the electrode carrier receives motion in the horizontal direction, whilst, when the slide and carrier are locked together, both parts move in the vertical direction.

As will be seen in the accompanying illustrations, Figs. 1 and 2, which show longitudinal and front sectional elevations of a portion of a welding machine, a hollow vertically movable slide B is mounted in a vertical guide A. At the lower end of the slide is arranged an electrode carrier C, which can move horizontally with respect to the

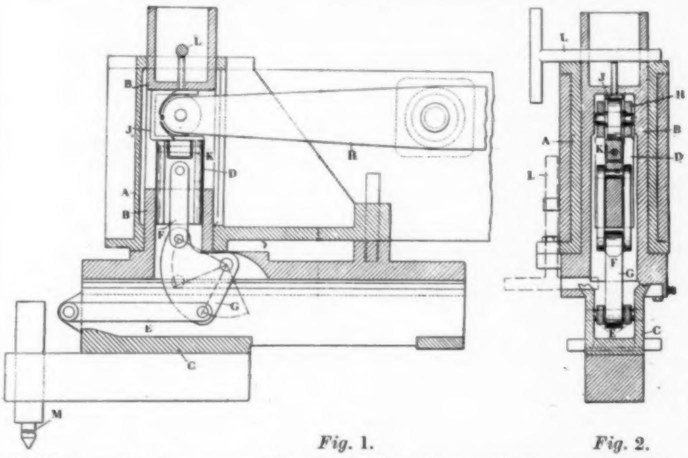


Fig. 1. *Fig. 2.*

Welding machine improvement for spot welding either vertically or horizontally.

slide B on guides. The carrier C is connected to a plunger D which moves within the slide by links E, F, and the bellcrank lever G. The link E is attached to the carrier and lever, and the link F is attached to the lever and plunger, as shown, the lever being pivoted on the slide.

An actuating lever H is pivoted at *i* on a fixed part of the machine carrying the guide A, and the operative end is connected to a shoe J situated within the slide B and attached by a pin K to the upper end of the plunger D.

A pin or cotter L can be inserted through a hole in the slide B, so that it rests on the upper end of the guide A for preventing motion of the slide relatively to the guide, as shown by full lines in Fig. 2. Horizontal motion is then given to the carrier C (on which is mounted the electrode M) through the plunger D and links and lever F, G, E. When vertical motion of the electrode is required, the pin L is removed and transferred to another position, in which it locks the carrier C to the slide B, the plunger D and its associated parts being then in the position shown in Fig. 1. As the carrier cannot then move relatively to the slide, and as the latter is free to move vertically, the slide and carrier move together in the vertical direction.

The electrode M shown in Fig. 1 is adapted for use with a vertical movement of the carrier. When the carrier is moved horizontally a cranked electrode is used, the lower end of the electrode being bent at right angles to the upper part.

This improvement enables one machine to operate successfully for either horizontal or vertical welding. It is not limited in its application to the one example shown, as modification can be effected, but the principle which combines an arrangement of parts to enable both operations to be performed is the same.

372,970. C. A. HADLEY and BRITISH ELECTRIC WELDING MACHINES, LTD., both of Dudley, patentees. May 19, 1932.

Aluminium as a Lubricant in Wire and Tube Making.

IN the cold-drawing or stamping of metals, especially to form wires, tubes, etc., a coating of aluminium is used as a lubricant. It may be applied as an aluminium paint, comprising preferably one part by volume of aluminium powder to three parts of a volatile liquid such as amyl acetate containing some nitrocellulose or other cellulose ester or ether or gums and drying oils to form a film. It is particularly applicable to the drawing of iron-chromium alloys of the type containing 10 to 40% of chromium and less than 0·3% of carbon. A bar of an iron alloy containing 25% chromium and 0·2% carbon is annealed, the scale is removed, and the bar is then painted with the aluminium paint, which is allowed to dry before drawing. These operations are repeated at intervals during successive drawing operations.

367,198. J. J. V. ARMSTRONG, 12, Church Street, Liverpool.

Cores for making Hollow Bars.

Metal tubes, hollow bars, etc., such as hollow drill steel, are made by rolling, forging, or drawing hollow billets on a core of a steel or ferrous alloy, which when stretched after rolling elongates uniformly along its length and, with certain exceptions, has a coefficient of heat expansion greater than that of the billet. A billet having a coefficient of expansion of 11×10^{-6} may be rolled on a core consisting of steel containing about 12% of manganese, 7% of nickel, and 0·5% of carbon, having a coefficient of expansion of 17×10^{-6}. Another suitable core contains 13·6% of carbon. After rolling, the core is subjected to tension, whereupon it may be drawn out. Cores of the above type which are excepted contain either 16% of chromium, 12% of nickel, and 0·1% of carbon, or 0·1 to 0·5% of carbon, 20 to 22% of chromium, and 7 to 9% of nickel, or 0·4 to 0·7% of carbon, 3 to 5% of chromium, 7 to 10% of nickel, and 5 to 10% of manganese, or 1 to 1·5% of carbon, and 11 to 14% of manganese, or up to 1% of carbon and 17 to 35% of manganese.

371,993. L. NORDEUFELT, Fagerata, Sweden. February 19, 1931.

Welding Rods for Ferrous Metals and Alloys

WELDING rods of chromium nickel steel alloys which are resistant to corrosion by the atmosphere, acids, etc., or to oxidation at high temperatures are used to weld ingot iron, grey cast iron, cast steel, cast silicon steel, and structural steels. The joints are stated to have high elongation, tensile strength, and working capacity. The rods may contain from 10–30% of chromium, and 2–30% of nickel, preferably 25% of chromium, 20% of nickel, and 0·15% of carbon. The rods may also contain tungsten molybdenum, titanium, vanadium, beryllium, etc. Such rods may contain 18% of chromium, 8% of nickel, 4% of molybdenum, and 0·15% of carbon, or 18% of chromium, 8% of nickel, 0·6% of titanium, and 0·12% of carbon, or 18% of chromium, 10% of nickel, 0·8% of tungsten, and 0·1% of carbon. Vessels for use with high pressures and temperatures and structural steel work may thus be welded.

372,678. F. KRUPP AKT.-GES., Essen, Germany. Sept 30, 1931.

Some Recent Contracts.

Among recent orders placed by Arcos, Ltd., on behalf of the U.S.S.R., the following are given in a list compiled by the Russo-British Chamber of Commerce:—Electric generators and motors, switchgear and winding equipment (£150,000), Metropolitan - Vickers Electrical Co., Ltd.; four tinning machines (£40,000), Melingriffith Co., Ltd., Cardiff; machine tools (£15,000), David Brown and Sons, Ltd., Huddersfield; pneumatic tools (£10,000, Broom and Wade, Ltd., High Wycombe; small steamship (£13,000), Arthur Stott and Co., Ltd., Newcastle-upon-Tyne; four 150-ton all-steel wagons (£8,000), Hurst, Nelson and Co., Ltd., Motherwell; high-speed steels (£8,000), Jonas and Colver (Novo), Ltd., Sheffield; trolley locomotives (£10,000), Greenwood and Batley, Ltd., Leeds; temperature-treating equipment (£5,500), Drayton Regulator and Instrument Co., Ltd., West Drayton; compressors (£5,000), Belliss and Morcom, Ltd., Birmingham; switchgear (£4,000), Ferguson, Pailing, Ltd., Manchester; steel, Hadfields, Ltd., Sheffield; wire, British Driver-Harris Co., Ltd., Manchester; rolling mill (£200,000, Davy Bros., Ltd., Sheffield; tube-rolling mill (£90,000), Wellmann Seaver Rolling Mill Co., Ltd., Darlaston; transfer cars for steelworks (£50,000), Newton, Chambers and Co., Ltd., Sheffield; electric resistance furnaces (£60,000), Birmingham Electric Furnaces, Ltd., and the Electric Resistance Co., Ltd., Birmingham; machine tools (£20,000), B.S.A. Tools, Ltd., Birmingham; machine tools (£13,000), Drummond Bros., Ltd., Guildford; axle billets (£20,000), United Steel Co., Ltd., Sheffield; six tank locomotives (£120,000), Beyer Peacock and Co., Ltd.

The British Steel Export Association has received a contract for 25,000 tons of steel plates from Arcos, Ltd., on behalf of the U.S.S.R. It has been allocated amongst practically all the British steelworks engaged in rolling plates. This order was secured in the face of severe Continental competition, and the promise of early delivery had an important influence.

Messrs. Harland and Wolff, Ltd., have received an order for a twin-screw passenger and cargo vessel for the Bombay Steam Navigation Co., Ltd. The hull will be constructed at the Company's Govan shipyard, and the machinery at their Belfast works. The new vessel will be about 200 ft. long, and will have two sets of triple-expansion engines, with one double-ended boiler suitable for burning coal or oil.

Dorman, Long, and Co., Ltd., have secured a £330,352 contract from West Ham Borough Council for a new high level road, one mile long and involving eight bridges, in connection with the scheme for improving road access to the docks.

Macintosh Cable Co., Ltd., of Derby, have received a £100,000 contract from the C.E.B. for power cables for the S.-W. England grid scheme.

Brookhurst Switchgear, Ltd., Chester, has received an order from the Cardiff Corporation electricity department for nine E.H.T. oil-pressure breakers. The contract covers three 250-ampere, three 350-ampere, one 750-ampere, and two 1500-ampere breakers, all 6,600 volts.

Yarrow and Co., Ltd., have received an order from the Burmah Oil Co. for an oil-fired, water-tube boiler, with air pre-heater, to be manufactured at Glasgow and shipped in pieces for re-erection in Burmah. The boiler is designed for a normal evaporation of 25,000 lb. per hour, a working pressure of 190 lb. per square inch, and steam temperature of 500° F.

Vaughan Crane Co., Ltd., has received an order for four 15-ton four-motor cranes and one 5-ton crane for the London and North-Eastern Railway Co.'s locomotive works at Darlington.

Negretti and Zambra have received a contract for the supply of 41 mercury-in-steel distance dial thermometers for each of the four new cruisers, H.M.S. *Leander, Orion, Neptune,* and *Achilles.*

The directors of the Southern Railway Co. have placed an order with William Denny and Brothers, Ltd., of Dumbarton, for a new steamship for the Jersey-France service, to take the place of the *Vera*. The new ship will have accommodation for about 900 passengers.

H. Tollemache and Co., Ltd., of Canada House, Norfolk Street, London, W.C. 2, have received a repeat order from the Carlton Main Colliery Co., Ltd., for the conversion of a further eight Lancashire boilers at Grimethorpe Colliery from hand to pulverised coal-firing. This installation, when completed, will be the largest Lancashire boiler plant in the world operated by pulversied coal.

The Pulsometer Engineering Co., Ltd., Reading, has received an order from the Hadleigh Urban District Council for supplying three sets of crude oil engines and centrifugal pumps (supply, erection, and fitting), two of which are to be provided with automatic starting and stopping switchgear at the pumping station.

Messrs. William Taylor and Sons (Glasgow), Ltd., have received a contract from the Galloway Water Power Co. for the foundation work and the steel and reinforced concrete work in connection with the Galloway Power Scheme.

Standard Telephones and Cables, Ltd., have received orders from the General Post Office for large extensions to the repeater stations at Fenny Stratford, Leeds, Liverpool, and Derby, and also for 150 positions of equipment at the new London Trunk Exchange; also for the supply and installation of a loaded telephone cable between Perth and Dundee.

Catalogues and Other Publications.

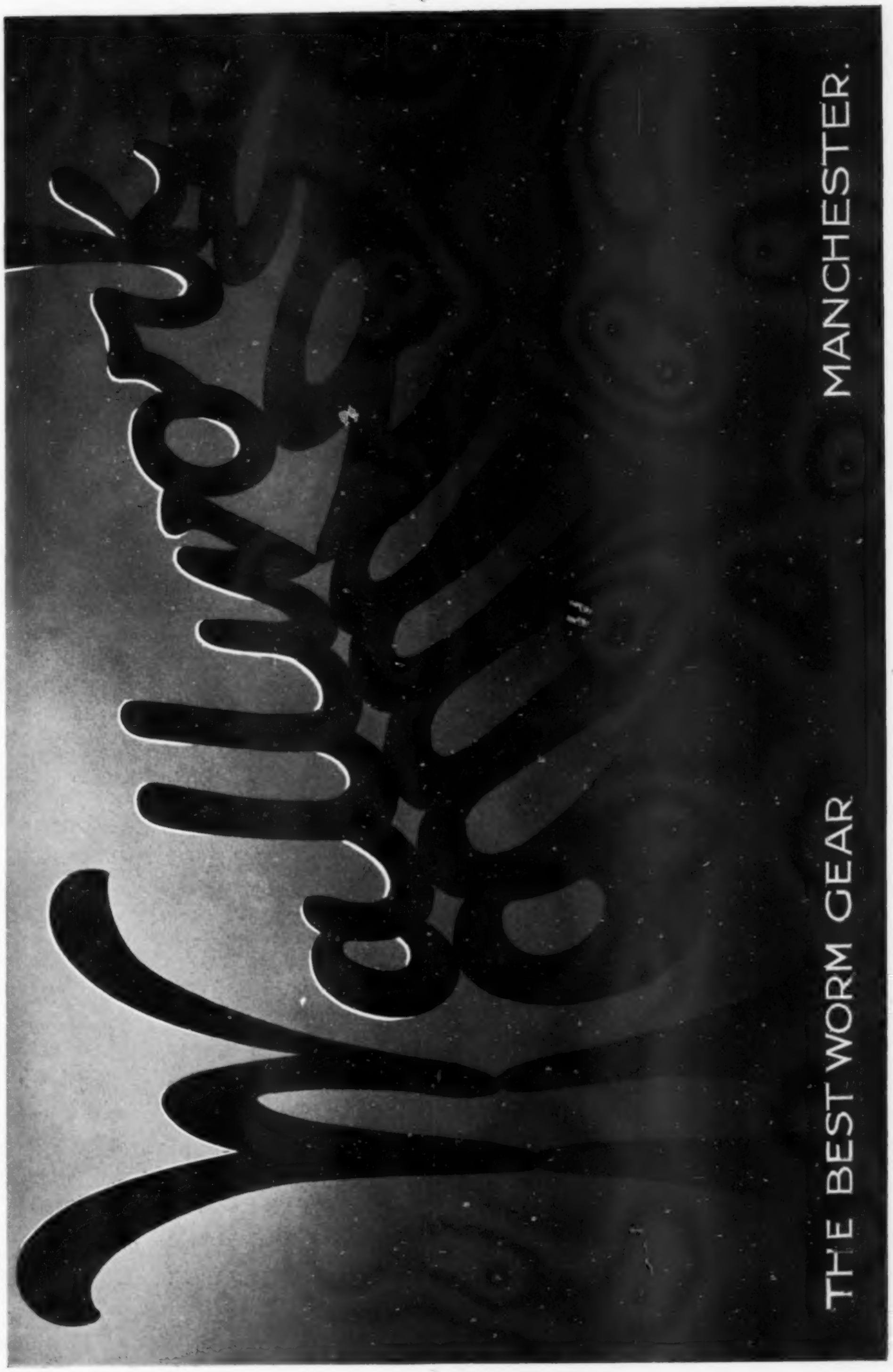
The oscillograph is now recognised as an almost indispensable aid to the investigatons of transient and rapidly varying electrical phenomena, and the increasing use of alternating currents has stimulated the demand for a compact semi-portable instrument which may easily be adapted for various tests. Such an instrument should be easy to operate, and sufficiently robust to withstand ordinary workshop conditions. Considerable information on the subject is contained in a publication recently issued by the Cambridge Instrument Co., Ltd., which is unique in that it deals exclusively with oscillographs. It contains details and illustrations of many diverse types, all of which have been specially designed and modified to meet with particular requirements in the electrical industry and for research purposes.

Since 1898, when this Company made their first oscillograph to the design of the late Mr. W. Duddell, they have been continuously developing the design, and an outstanding feature of the modern design is that simultaneous records may be obtained from three or six vibrators which may be a combination of the electromagnetic, the electrostatic, or watt-element types—only one camera and one source of light being required. Those interested should obtain this publication from 45, Grosvenor Place, London, S.W. 1.

An interesting and informative booklet has been published on modern methods of case-hardening. It contains valuable information on the process and emphasises a particular method usually known as "Cyanide-hardening." The booklet contains 44 pages; of handy size and well illustrated, it is excellently produced. It is issued by Imperial Chemical Industries, Ltd., Millbank, London, S.W. 1.

Sands, Clays, and Minerals.

The second issue of the above-named publication worthily maintains the quality of the first issue and will be appreciated by readers covering a wide field of interest. The primary object of this publication is to assist in the development of the mineral wealth of the Empire, and in this issue Dr. Camsell shows that Canada shipped her surplus copper to U.S.A., whereas Great Britain, in the same year, bought 80 per cent. of her copper from foreign countries. In this issue new ground is broken and useful information given on: "Setting Firebrick in Marine Boilers"; a contribution from the Department of Mines, Ottawa, deals with valuable minerals; Fuller's earth is described, and a further instalment of trade marks of British firebrick, in colour, is given. Australian opals are discussed, and an interesting coloured illustration accompanies the text. Containing about 60 pages, this issue contains much interesting information, and is obtainable from Mr. A. L. Curtis, Westmoor Laboratory, Chatteris, for an annual subscription of 5s. (foreign subscribers, 5s. 6d.), which covers four quarterly issues.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Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	35 15 0
NOMINAL 4-6% Carbon, scale 8/- per unit	,,	25 0 0
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NOMINAL 8-10% Carbon, scale 8/- per unit	,,	23 5 0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	36 5 0
Guar. max. 1% Carbon, scale 14/- per unit	,,	40 15 0
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	44 10 0
‡Manganese Metal 96-98% Mn.	lb.	0 1 4
‡Metallic Chromium	,,	0 2 8
§ Ferro-Vanadium 25-50%	,,	0 12 8
§ Spiegel, 18-20%	ton	7 10 0
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	5 17 6
20/30% basis 25%, scale 3/6 per unit	,,	8 10 0
45/50% basis 45%, scale 5/- per unit	,,	13 15 0
70/80% basis 75%, scale 7/- per unit	,,	19 0 0
90/95% basis 90%, scale 10/- per unit	,,	30 0 0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	15 2 6
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 6
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Durham	1 1 0 to	1 4 0
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Crown Bars …. £9 15 0 to	10 0 0
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Nut and Bolt Bars ……… £8 7 6 to	8 12 6
Gas Strip	10 12 6
S. Yorks.—	
Best Bars	10 10 0
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PHOSPHOR BRONZE.

*Bars, " Tank " brand, 1 in. dia. and upwards—Solid	lb.	8d.
*Cored Bars	,,	1⁄ d
†Strip	,,	10½d.
†Sheet to 10 W.G.	,,	10¾d
†Wire	,,	11¼d.
†Rods	,,	11d
†Tubes	,,	1/4
†Castings	,,	1/1¼

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£3 7 6
Foundry No. 1	3 10 0
,, No. 3	3 7 6
N.E. Coast—	
Hematite No. 1	3 0 0
Foundry No. 1	3 1 0
,, No. 3	2 18 6
,, No. 4	2 17 6
Cleveland—	
Foundry No. 3	2 18 6
,, No. 4	2 17 6
Silicon Iron	3 1 0
Forge No. 4	2 17 0
Midlands—	
N. Staffs Forge No. 4	3 1 0
,, Foundry No. 3	3 6 0
Northants—	
Forge No. 4	2 17 6
Foundry No. 3	3 2 6
Derbyshire Forge	3 1 0
,, Foundry No. 3	3 6 0
West Coast Hematite	3 6 0
East ,, ,, No. 1	3 0 0

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	92 KRONOR.
Billets ………. £12 13 6 to	£16 0 0
Wire Rods ……. £14 12 0 ,,	£17 12 6
Rolled Bars (dead soft) ……. £10 4 0 ,,	£11 11 0
Rolled Charcoal Iron Bars ……. —	£16 0 0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£25 0 0
,, Braziery	23 0 0
,, Wire	—
Brass	16 0 0
Gun Metal	21 0 0
Zinc	8 10 0
Aluminium Cuttings	72 0 0
Lead	10 10 0
Heavy Steel—	
S. Wales	1 18 6
Scotland	1 12 6
Cleveland	1 15 0
Cast Iron—	
Midlands	1 15 6
S. Wales	1 19 0
Cleveland	1 16 0
Steel Turnings—	
Cleveland	1 7 6
Midlands	0 19 6
Cast Iron Borings—	
Cleveland	1 2 6
Scotland	1 10 0

SPELTER.

G.O.B. Official	—
Hard	£13 0 0
English	16 7 6
India	14 5 0
Re-melted	15 0 0

STEEL.

Ship, Bridge, and Tank Plates—	
Scotland	£8 15 0
North-East Coast	8 15 0
Midlands	8 17 6
Boiler Plates (Land), Scotland	9 0 0
,, ,, (Marine) ,,	—
,, ,, (Land), N.E. Coast	10 0 0
,, ,, (Marine) ,,	10 10 0
Angles, Scotland	8 7 6
,, North-East Coast	8 7 6
,, Midlands	8 7 6
Joists	8 15 0
Heavy Rails	8 10 0
Fishplates	12 0 0
Light Rails …. £8 10 0 to	8 15 0
Sheffield—	
Siemens Acid Billets	9 2 6
Hard Basic .. £8 2 6 and	8 12 6
Medium Basic .. £6 12 6 and	7 2 6
Soft Basic	6 0 0
Hoops ………. £9 10 0 to	9 15 0
Manchester—	
Hoops ………. £9 0 0 to	10 0 0
Scotland, Sheets 24 B.G.	10 5 0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten.	lb.	2/-
Finished Bars 18% Tungsten.	,,	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to ⅛ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£154 10 0
English	155 5 0
Australian	159 12 6
Eastern	159 15 0
Tin Plates I.C. 20 × 14 box	0 16 0
Block Tin (Cash)	155 5 0

ZINC.

English Sheets	£24 10 0
Rods	27 0 0
Battery Plates	—

* McKechnie Brothers, Ltd., quoted Nov. 11. † C. Clifford & Son, Ltd., quoted Nov. 11. ‡ Murex Limited, quoted Nov. 11.

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted Nov. 11, ex warehouse.